PROCEEDINGS

OF THE

AMERICAN PHILOSOPHICAL SOCIETY,

HELD AT PHILADELPHIA, FOR PROMOTING USEFUL KNOWLEDGE.

VOL. XX. JANUARY TO JUNE, 1882. No. 111.

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EXTRACT FROM THE BY-LAWS.

CHAPTER XII.

OF THE MAGELLANIC FUND.

SECTION 1. John Hyacinth de Magellan, in London, having in the year 1786 offered to the Society, as a donation, the sum of two hundred guineas, to be by them vested in a secure and permanent fund, to the end that the interest arising therefrom should be annually disposed of in premiums, to be adjudged by them to the author of the best discovery, or most useful invention, relating to Navigation, Astronomy, or Natural Philosophy (mere natural history only excepted); and the Society having accepted of the above donation, they hereby publish the conditions, prescribed by the donor and agreed to by the Society, upon which the said annual premiums will be awarded.

CONDITIONS OF THE MAGELLANIC PREMIUM.

1. The candidate shall send his discovery, invention or improvement, addressed to the President, or one of the Vice-Presidents of the Society, free of postage or other charges; and shall distinguish his performance by some motto, device, or other signature, at his pleasure. Together with his discovery, invention, or improvement, he shall also send a sealed letter containing the same motto, device, or signature, and subscribed with the real name and place of residence of the author.

2. Persons of any nation, sect or denomination whatever, shall be admitted as candidates for this premium.

3. No discovery, invention or improvement shall be entitled to this premium, which hath been already published, or for which the author hath been publicly rewarded elsewhere,

4. The candidate shall communicate his discovery, invention or improvement, either in the English, French, German, or Latin language.

5. All such communications shall be publicly read or exhibited to the Society at some stated meeting, not less than one month previous to the day of adjudication, and shall at all times be open to the inspection of such members as shall desire it. But no member shall carry home with

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On the Origin and Drainage of the Basins of the Great Lakes. By J. S. Newberry.

(*Read before the American Philosophical Society, November 4, 1881.*)

Having lived for half my life on the shores of Lake Erie, and beginning my geological studies there at an early age, the mode of formation of this water basin naturally became a subject of observation and thought with me. Subsequently, I for ten years owned a country place on one of the islands near the west end of the lake, and during the summer residence of my family there I had a more satisfactory opportunity for the study of the structure of these islands than can be enjoyed by any one now, since some of the most striking cliffs and rock surfaces have been quarried away or covered with buildings.

The interest which I acquired in the subject also led me to visit and examine with some care the whole chain of lakes, and to follow this line of drainage from Duluth, Lake Superior, to its present outlet at the mouth of the St. Lawrence, and its ancient one at New York.

The results of the observations thus made were communicated to the public in "*Notes on the Surface Geology of the Basin of the Great Lakes*" (Boston Natural Historical Society, 1862); "*Geological Survey of Ohio, Report of Progress for 1869;*" "*The Surface Geology of the Basin of the Great Lakes and the Valley of the Mississippi*" (Lyceum of Natural Historical Society, New York, 1869); "*The Surface Geology of Ohio*" (Report of Geological Survey of Ohio, Vol. ii, 1874); "*The Geological History of New York Island and Harbor*" (Popular Science Monthly, 1878).

In the progress of these investigations, I discovered what had not before attracted attention, that (1), at one time the eastern and middle portions of the continent stood considerably higher above the ocean than at the present time; (2), that an extensive system of drainage lines which once traversed the continent had been subsequently more or less filled up and obliterated, generally by the drift of the Ice period; (3), that our modern rivers had often deserted their ancient valleys altogether, and flowed some-

times hundreds of feet above their former beds; and (4), that glaciers had once occupied the basins of our great lakes, moving in the lines of their major axes.*

These facts formed the basis of the history of the formation of our lake basins which I then reported.

This history may be briefly epitomized as follows:—

1st. In the Tertiary age a great river traversed and drained the basin of the lakes, rising in the highlands north of Lake Superior, and terminating in the Atlantic ocean eighty miles south and east of New York.

2d. In the advent and decline of the Ice period, local glaciers descending from the Canadian highlands and following the lines of lowest level, scooped out expansions of the river valleys forming the basins of the present lakes.

3d. These basins were connected by cañons which cut the rock barriers separating them, and through which flowed their surplus waters.

4th. At the culmination of the Ice period a general ice sheet filled and overflowed the lake basin, choking up the river valleys with boulder clay, and obliterating the details of local topography.

5th. After the retreat of the glaciers the great river which drained the lake basin, finding its old channel obstructed, chose for itself a new route. Following the line of lowest levels it left its former trough buried under the Grand Sable, to cross a spur of the Canadian highlands at Sault St. Marie, again it crossed a point extending northward from the Alleghany highlands at Niagara, and, finally, its Mohawk channel being obstructed it chose a new route by the Thousand Islands and Lachine Rapids to the Gulf of St. Lawrence.

A large number of facts sustaining these conclusions are given in the papers to which reference has been made, but a repetition of that which has been so fully stated would be superfluous here.

In tracing the course of the ancient river which drained the lake basin, I ventured to predict that a buried channel would be found connecting the basins of Lake Erie and Lake Ontario, "somewhere between Long Point and the western end of Lake Ontario."

This channel Prof. J. W. Spencer, of King's College, Windsor, N. S., claims to have discovered; and in a paper published in the last issue of the Proceedings of the American Philosophical Society, he maps and describes it, locating it where I had predicted its discovery, although he says it is a

*The first suggestion of the existence of these ancient buried channels was given by the borings for oil in the valley of the Cuyahoga at Cleveland, where I then resided, and in the valleys of other tributaries to the Lake system or the Ohio. Every stream bed in that section was at that time probed for petroleum, and in most cases the rock bottoms of the valleys were only reached after penetrating a considerable mass of clay beneath the present stream. At Cleveland the rock bottom of the old valley is two hundred feet below the bottom of the river, and the lake basin into which it flows, though silted up to within sixty feet of the surface of the water, was once excavated to a still greater depth than the river trough.

channel "of which there was no clue or even suggestion until working up the origin of the Dundas valley." Prof. Spencer also does much more than describe this buried channel in the paper referred to, for he there discusses at length the origin of the lake basins, and reaches conclusions which are in some respects at variance with those previously published by myself.

The points of difference between us are briefly these; I had claimed the existence of an ancient river flowing from Lake Superior through the lake basin and down the Mohawk valley into the trough of the Hudson, and thence to the ocean by New York. The valley of this stream, locally expanded into boat-shaped basins by glacial action, according to my view, formed the basins of the great lakes.

Prof. Spencer denies that glaciers have played any part in the formation of the lake basins, and more sweepingly that ice has any excavating power. He also rejects the theory that the outlet of the lake basin was by the Mohawk valley, saying, "the Mohawk course will not answer as the Geological Survey of Pennsylvania has shown, for at Little Falls, Herkimer Co., the Mohawk flows over metamorphic rocks."

Meeting the last objection first, I venture to say that the Geological Survey of Pennsylvania has not shown that the outlet of the lake basin through the Mohawk valley "wont do." The fact that the present Mohawk river flows over rocks at Little Falls is no new discovery, as it could hardly escape the observation of any traveler over the New York Central Railroad, but there is ample room in the adjacent country, where heavy beds of drift cover the rock, for the continuation of the old, deeply-cut Mohawk valley. In the country about Little Falls, not only is there room for such a channel, but the facts necessitate its existence. The rocky barriers over which the Niagara and St. Mary's flow are equally conclusive evidence against a continuous buried channel connecting the great lakes,—in which we both believe.

In regard to the agency of glaciers in excavating the lake basins I think no one who will carefully observe the facts, will hesitate to ascribe to them an important function. It is true that Prof. Whitney denies that ice has ever excavated a lake basin, and Prof. Spencer echoes and endorses the statement; but it is also true that Prof. Ramsay, Director of the Geological Survey of England, claims that *all* lake basins have been excavated by ice, and Prof. J. Le Conte whose range of observation has been extensive, attributes the origin of Lake Tahoe and other lakes in the Sierra to this cause. They have also supported their views of the power of ice as an erosive agent, not simply by the authority of their names, but by an imposing array of facts. In such circumstances those who deny any excavating power to glaciers can hardly expect their curt dismissal of the ice theory to be accepted without some sort of evidence beside their personal assertion. It has happened to me to have opportunities of studying the effect of glaciers ancient and modern in many countries, and I am compelled to say that the statements that ice has no erosive power, and has made no im-

pression on topography except by the accumulation of morainic material, and also that ice has had no agency in the excavating of the lake basins, are alike disproved by my own observations. Any one who has visited the present termini of the Alpine glaciers cannot fail to have remarked the *roches moutonnées* and the broadly excavated troughs, the work of the glaciers when they had greater reach. He will also have noticed that these glacial troughs, under and beyond the present glaciers, are furrowed by deep and narrow channels, the work of the streams flowing from the melting ice. Here we obtain conclusive evidence that ice *has* erosive power, and have, on a small scale, typical examples of the kinds of erosion wrought by ice and water. The higher portions of the Sierra Nevada, and the whole summit of the Cascade mountains bear such indisputable evidence of the erosive action of ice that it is incomprehensible that any one should have seen this record and deny its validity. On the Cascade mountains there are thousands of square miles over which the rocks are planed down, grooved and furrowed, where the rough and ragged summits are reduced to *roches moutonnées* and enough material has been removed by ice to fill all the water-cut channels of the continent. In the Report of the Geological Survey of Ohio I have described in detail the evidence of the action of ice in forming the basin of Lake Erie. No one can visit the group of islands off Sandusky without being convinced that they are carved by ice out of the solid rock. Their sides and surfaces are everywhere glaciated, and areas of acres in extent planed down to the smoothness of a house floor. The corals and other fossils which fill the limestone are here cut across as smoothly as it could be done by hand; and as I have elsewhere shown, the direction of the furrows and the trails left behind chert masses in the limestone, prove that the ice moved in the line of the major axis of Lake Erie, and from the north-east toward the south-west. Similar facts both in regard to rock striation and the transport of material have been observed about Lake Ontario, Lake Huron, Lake Michigan and Lake Superior.

The manner in which ice accomplishes the erosion effected by it, is no mystery, as any one who has seen a glacier has seen the agent in action. The soft ice simply becomes a great emery wheel. Rocks, gravel and sand are frozen into its under surface or are spread beneath it and pressed down upon its bed with the enormous weight of the moving mass; the result is a grinding that nothing can resist. The ground up material is "till" or boulder clay, sand, gravel and boulders, and this residue, perhaps insignificant in quantity compared with the amount produced, covers literally hundreds of thousands of square miles on this continent alone. How, in the face of these facts, can any one say, ice has no erosive power? Prof. Spencer misunderstands and misrepresents me when he imputes to me any vacillation of opinion or any uncertainty in regard to the agencies which have excavated the lake basins. From the first I have recognized the existence of an ancient river draining the lake basins at a low level, and was by many years the first to indicate the existence of such a stream, but

I have never for an instant doubted that the erosive action of this river was supplemented and modified by local glaciers. It is quite beyond the reach of fluvial erosion,—of which in the cañons of the Colorado, I have studied the best examples extant,—to form basins like those of our great lakes; and while it gives me pleasure to find in Prof. Spencer's discovery a confirmation of the prediction made years ago, and to give him credit for the sagacity and industry which marks his investigations, I cannot but feel that before attempting to write a general history of the Lake basins, it would have been well to have gone in person over all the ground under discussion.

Discussion.

Mr. Lesley remarked that in all controversies over the Glacial hypothesis, as it used to be called, the Glacial theory as it has now well established itself to be, a vast number of observed facts are accepted on all hands as part of the actual human knowledge. No one now thinks of disputing the former extension of existing glaciers; nor the former existence of sheets of ice over large areas of the earth's surface, where nothing like a glacier is now noticeable even at the close of the severest winters; nor the meaning of the scratches and grooves, clays and gravels, moraines and kames, pot holes, ponds, terraces, sand dams, reversed drainage, and whatever else are the characteristic marks and vestiges of the agency of the ice which once covered such areas. All geologists who have studied existing glaciers in the Alps, for instance, or who have acquainted themselves with their character and action through good descriptions of them, take precisely the same view of the circumstances.

What geologists are not yet agreed upon is not whether moving ice once covered now fertile districts, but the precise limits of these glaciated districts; not that all moving ice moves rocks, but precisely in what manner the rocks move with, on, in or under the ice; not that glaciers deposit heterogenous materials, but precisely what part water, melted ice, plays in the drama, and how one can best distinguish its work from that done by the ice itself, unmelted, in and of itself; not whether there has been an age of ice, but whether there were not two or more, and whether human beings began to live in an earlier, in a medial, or in a later age; and above all, not whether the surface of glaciated regions was modified by the long or short, single or repeated passage of ice over them, but precisely to what extent this modification went.

In a word, the Glacial Theory, perfectly well defined and accepted by all in the clear light of long continued, thorough and consistent investigation, is still surrounded by a penumbra of Glacial Hypotheses, about which very enthusiastic and dogmatic geologists are disposed to debate with a great deal of personal warmth, as if their personal reputation for genuine scientific ability was involved. The fact is, some of the questions thus presented are so difficult of any precise definition that we must wait long for their answers.

The most difficult of all these questions has naturally excited the most strenuous discussion:—the excavatory power of ice.

Every geologist knows that an uncertain amount of erosion must be explained by ancient ice movements; for, the eroding action of glaciers may be studied in Alpine valleys as it is now going on. But some think this erosion to be so insignificant as to be justly compared to the sandpaper smoothing-off of a roughly-planed board; while others please their imaginations with its incredible force and magnitude, and describe it as ploughing out Alpine valleys, and excavating American lakes. Recent works on the Glacial Age might be quoted to show that conjectures of all grades between these two extremes are accepted by their geological authors—vague postulates, or general propositions, taken for granted, without being subjected to any mathematical analysis—as a groundwork for the consideration and description of old and new local facts.

It is needless to say that no personal sentiment on the subject can have a scientific value. For my own part, I entertain a lively persuasion in favor of the sandpaper end of the series of hypotheses; but I can assign no higher value to this persuasion, or personal opinion, nor do I think it can any more efficiently secure scientific results, than an impulse towards the opposite, or lake excavating prejudice. It is after all merely a prejudice, but a prejudice in favor of the preponderance of a multitude of facts which bear upon the subject under discussion; facts which I think have never yet been placed in the strongest light; facts of topography, especially abundant in regions near to but outside of glaciated regions.

There are two principal lines of investigation, it seems to me, which may lead us to a hopeful elucidation of the question of *how much of our topography has been effected by ice.*

1. We may take up one feature of topography after another, and by a process of exclusion, narrow down the field of ice-action until what is left shall remain reasonably certain to be due to ice alone; and

2. We may study, directly and mathematically, by number, weight, bulk and velocity, the work actually done by an existing glacier, and infer by strict comparison the possible limits of ice-work over any given glaciated region.

Thus, to take the last first, let us ask what is the potential of eroding energy in the case of a glacier?

Pure ice, of course, has no scratching power. The facility with which it moulds itself upon surfaces, is shown, in an astonishing manner, by grooves on the underside of a moving glacier, produced by large stones lying quite loose upon the bed-rock, and prevented from slipping forward with the ice by some slightly obstructive irregularity of the bed-rock surface. The common notion is that all such stones are necessarily embedded by the ice and used as scratchers, or eroding tools. But at least some of them are not so taken up by the ice, which slips smoothly over them, retaining as a groove the shape of their cross section, for many yards after passing their position.

The number of stones thus inoperative at the base of a glacier is one of the factors in the equation of erosion.

That ice uses sand, gravel and boulder débris to scratch its rock bed is not doubted by any one. The abrupt termination of striæ, deepening and widening to their abrupt termination, was one of the earliest observed facts, and was explained on the old diluvial theory, and the iceberg theory, by the arrest and rotation of the block which served as a graving tool, fixed in the ice, or by the breaking off of the point of the tool.

The chapters of James Hall's Report of the Geology of the Western District of New York, published in 1844, which describe the Drift and Glaciation of that District suffice to show how carefully these phenomena were studied fifty years ago. Dr. Newberry and other ultra-erosionists would do well to note what Hall says (on page 331) in evidence of the comparatively slight force necessary for producing the grooves and polished surfaces, the overturning of bed plates, and transport of fragments, from which such exaggerated theoretical consequences are deduced.

In those really admirable chapters may be found the earliest hints of the now accepted activity of subglacial water, loaded with débris, in doing much of the work wrongly ascribed to ice.

The actual erosive power of rock-set ice must certainly be susceptible of an approximately accurate mathematical calculation,

Its differential is: *one stone*, held by the ice against the bed-rock with a certain pressure—the stone of a certain hardness (a)—the bed-rock of a certain hardness (b)—the ice-grasp of the stone, of a certain plasticity (c) —the maximum pressure exerted by the weight of the ice, up to the point-crushing degree (d).

It is evidently wrong to make the total weight of the column of ice above the tool a measure of the engraving. Were the ice piled to the height of miles, its graving power would be no greater than that of a column of ice weighing just enough to crush the point of the tool. All the declamation in books respecting the enormous erosive force of a sheet of ice several thousand feet thick pressing down upon and moving over sandstone, limestone and shale strata is simply wasted. A thousand miles thickness of pure ice moving over a bed of clay, would erode it no more than a thousand miles of water would. If it held stones, they would be simply embedded in the clay and left behind. If they moved over any kind of solid rock, they would simply be reduced to fine sand or mud, and act as a *lubricating medium*, protecting the bed-plate surface from erosion.

Every glacier must slip to a greater or less extent upon a lubricated surface, consisting principally of muddy water, or watery mud. The thicker the glacier the more of this lubricant it will have beneath it. The law of increase of temperature descending from the surface must act in ice as in rock. Where the bare rock surface of the earth has a mean temperature of 32°, the temperature at 1000 feet down stands at, say, 52°. Were a glacier 3000 feet deep to remain for a century immovable over a region the normal mean air temperature of which is

32°,—while it would waste slowly at its surface by spontaneous evaporation, and more rapidly at its surface by solar heat—it would waste at its base also by the upward transmission of earth heat. But this waste would be represented by so much water, which under an immovable glacier would form a lake. Under a movable glacier it helps to form a river, and the river which issues at the terminal surface moraine brings out the evidences of the lubricant, as "mountain meal."

Every glacier must be made cavernous by its river, and along the caverns produced by the river and its branches are collected and deposited or rolled forward all the stones in the glacier while those upon its surface (or melted out to its surface, by the upper waste), ride down to its lower end.

The much larger part of the erosive action of a glacier must therefore be of the nature of river erosion; while a certain percentage of it may be of the nature of engraving. But if so, then our knowledge of river erosion must direct us in the investigation of glacial erosion.

River erosion is local and interrupted. Parts of a river bed are filling up, while reefs and barriers are being cut away. So, under a glacier, the loci of erosion must be few and of limited extent. Behind these the rolled glacial débris are covering and protecting the bed rock instead of eroding it. Our kames show therefore not only that Glaciers are feeble eroders, but that they are great depositors and protectors of the earth surface.

We may go one step further, and show how in the age of ice the usual erosion of our topography was almost stopped and forbidden by the ice.

For, the topography of the earth's surface is evidently due to rain, softening the surface—to rills, removing the softened surface—to brooks, sweeping the collections made by rills, down through the brook-vales and ravines which they have made,—until the process of erosion is reduced to a minimum where river deposits commence. Rivers never erode, except at rock barriers—or, in rainless regions, where they saw strait down, using their whole débris.

Now, in the ice age, the ice-covering protected the whole country from rain, rill and brook erosion, and the process of topographical modification of the earth's surface ceased, and was not resumed until the close of that age. What erosion took place, must have been exclusively confined to the lines of subglacial rivers and their branches, along the subglacial caverns. In a continental ice-flow crevasses were impossible, except along a few lines of escarpment.

The rain, therefore, in the ice age must have constituted a great riseau of superglacial drainage incapable of eroding the subglacial topography; in fact removed from it hundreds and even one or two thousand feet from it vertically. If the Canadian ice had a surface slope southward, towards Pennsylvania and Ohio, or south-westward up Lake Erie and across Illinois, then mighty rivers, heading in the Laurentian mountains and the Adirondacks, must have flowed for a long time over the upper surface of the ice

sheet, southward and south-westward into the Mississippi valley—without affecting the previously constituted topography beneath the ice—of which previously constituted topography the Lake Basins were an essential part and grand feature.

Meanwhile, a totally different system of drainage was carrying on its work of transportation beneath the ice sheet, in an opposite direction, northward (from Pennsylvania and Ohio) and eastward, through the lake basins. But this lower or sub-ice river system, deprived of *direct* alimentation from rain, must have been inferior in volume and power to the upper or surface-ice river system; although it may have received here and there through the ice sheet considerable accessions of surface rain water.

I do not wish to discuss here the line of Prof. Spencer's great river, nor the claim of Prof. Newberry to the discovery, years ago, of its debouchement, via the Mohawk and Hudson valleys, into the ocean at New York, except to remark that Prof. Newberry does not seem to appreciate Prof. Spencer's chief difficulty. It is not that the rocks appear at Little Falls; but that his Ontario river ran in a bed more than 780 feet beneath the present level of the lake, and therefore more than 900 feet below Little Falls, and the demonstration of a buried, concealed, old river channel nearly 1000 feet deep anywhere alongside of the Little Falls exposure seems a rather hopeless task. But worse than that; the Mohawk valley east of Little Falls, is barred by rock ranges 300 or 400 feet high, through which the Mohawk cuts a cañon, where its bed is at least 900 feet above the old river bed in the lake.*

I wish to confine my remarks to the feeble erosive power of the Canadian ice-sheet, as a particularly inefficient kind of glacier, and to the probable possibility of a mathematical demonstration of the feeble erosive power of any glacier, even in the most favorable circumstances.

Taking one stone graving-tool as the differential of *means*;—the engraving quality of that stone tool (under the conditions (a), (b), (c), (d) above stated) as the differential of *power*;—and the destruction of bed-rock by that stone-tool during its life as a tool, as the differential of *effect produced, i. e.* of erosion,—then,—to obtain a transcendental maximum, we must multiply one stone-tool (in area) by the total width and total length of the ice bottom; *i. e.* we must stud the whole bottom of the glacier with tools; keep them all at work, each one for the whole length of time of its descent from the upper to the lower end of the glacier;—replace those that are lost or spoiled by fresh ones;—and repeat the operation during the entire life of the glacier.

It is evident that this transcendental maximum if it could be calculated, would be of little value, in as much as it would almost infinitely exceed the actual practical erosive power of any given glacier.

But it would be the best starting point for a reasonable discussion of the erosive power of glaciers; and it seems to me, that if the calculation were

*See my notes to Dr. Spencer's appendix, at the end of White's Report of Progress, 2d. Geol, Sur. of Pa., Q. 4, 1881, p. 403.

made, it would have the effect of putting a stop to much of that vague babble about the "immense" "enormous" "amazing" influence of the ice age in sculpturing the surface of our planet, which has in some respects demoralized our science.

Had the age of ice commenced in Laurentian days or even in Permian times and lasted until now, we should certainly be compelled to ascribe most of our topography to the action of ice. But as the ice age was late and comparatively short, we must consider its effect upon our topography not only local but slight.

The second line of argument, therefore, is a very simple one. We should enquire first, what are the main features, the characteristic elements of our topography; and secondly, whether those be essentially the same in the glaciated and in the nonglaciated regions. If we find them to be identically the same in both regions, then, it follows, as a matter of course, that they cannot be ascribed to ice.

This line of argument I have taken numerous occasions, in past years, to follow out, and I have shown that the great lake basins of the north are in all (but one respect) topographically like the great valleys of the south and therefore *not* excavated by ice. The one item of exception is, that they have been more or less filled with the débris of the ice sheet, and afterwards with water dammed in behind glacial deposits. So far from the glacier having excavated them, it has simply buried them.

The argument pursued on this grand scale, repeats itself on a small scale now that the Terminal Moraine has been traced across the mountains and valleys of New Jersey and Pennsylvania. If the glacier covered the top of the Kittatinny mountain, for example, along its whole course from the Hudson to the Delaware, and for some miles west of the Delaware, and did *not* cover it anywhere along its whole course through Pennsylvania, Maryland and Virginia (and these facts are now demonstrated)—and if, notwithstanding, the mountain in its north-eastern prolongation is precisely the same as in its south-western prolongation—it follows without argument that it existed in its present form before the ice age, and was merely a little *sandpapered* by the ice during the ice age.

What is true of the Kittatinny, is true of the (Catskill) Pocono mountain plateau behind it, and of the Orwigsburg or Delaware river (Upper Silurian and Devonian) valley which separates the two ranges. Across this broad valley (the analogue of Lake Erie) the Terminal moraine runs west of Stroudsburg. The topography of the valley east of the moraine precisely resembles the topography of the valley west of the moraine, only that it is covered with drift material and marked with scratches. Of course the valley existed before the ice age, and the glacier merely polished its surfaces and *protected parts of it from subsequent erosion;* just as the glacier *protected lake Erie from erosion,* while it scratched the islands of which Prof. Newberry speaks, and all the hard outcrops, around it, as described by James Hall in New York, by Carll, White and others in Pennsylvaina, and by Dr. Newberry in Ohio.

And so of each valley and each mountain successively as one follows the terminal moraine north-westward, across the gorge of the Lehigh, across Hellkitchen mountain, across Conyngham valley, across the Nescopee mountain, across the Susquehanna above Berwick, across the Schickshinny mountain, near its west end, across the Muncy hills, across the Alleghany mountain north-east of Williamsport, across the Loyalsock ravine, and the Cañon of Lycoming creek, the plateau of Potter county, to its great angle north of Olean and Salamanca in New York.

Along this whole line, the topography to the east (under the ice) is precisely the same as the topography to the west (where ice has never been) and the only distinction observable is this: that west of the great moraine there is no drift and no lakes; east of the moraine the whole surface is sheeted with drift and spotted with ponds;—and all the scratches point south-south-westward, the ice evidently having moved from the Adirondacks.

From Salamanca the Terminal moraine has been traced by Mr. Lewis and Mr. Wright as a nearly straight ridge of trash, south-westward, across Western Pennsylvania to the Ohio line (near Darlington) 13 miles north of the Ohio river; the scratches all pointing S. S. E. and S. as if coming square across Lake Erie and ascending the highlands to the south of it. Nowhere along this line has it affected the topography; it has merely deposited drift, and choked the ancient valleys so as to reverse the drainage. Mr. Carll has pointed out the noses of hill-spurs which he thinks were sharpened by the ice; but even this slight modification of the pre-existing topography, occurs at places lying outside or to the south of the terminal moraine, and we must therefore find some other explanation for it.

It seems unreasonable in the highest degree therefore to speak of the glacial erosion of Lake Erie and Lake Ontario, when it is evident that the ice sheet was perfectly incompetent to erode the countries which it invaded, and left them everywhere precisely in the topographical condition in which it found them; merely scratching their rock exposures, incumbering and embarassing somewhat their lines of drainage, spreading a slight sheet of drift material over them, and tearing a few blocks out of the looser outcrops and depositing these blocks after a short transit; often on higher levels, and sometimes on much higher levels; for Mr. Lewis has found Helderburg blocks carried completely to the top of the Kittatinny mountain.

An Obituary Notice of William E. DuBois. By Robert Patterson.

(*Read before the American Philosophical Society, November 18, 1881.*)

William Ewing DuBois was born at Doylestown, Pennsylvania, December 15, 1810. Through his father, Rev. Uriah DuBois, he was descended from Louis DuBois, a French Huguenot of honorable extraction, who emigrated to America in 1660, seeking freedom of religious worship, and, in connection with others of his countrymen, formed the settlement of New Paltz, Ulster county, New York. Through his mother, Martha Patterson, daughter of Professor Robert Patterson, of the University of Pennsylvania, he inherited the Scotch-Irish element which has exerted so marked an influence in the development of our country.

The father of Mr. DuBois was a Presbyterian clergyman, in charge of churches in and near Doylestown, and was Principal of the Union Academy at that place, a classical school then and afterwards of high reputation. He was greatly respected, both as preacher and teacher. His death, at a comparatively early age, left a large family, in narrow circumstances, to be provided for. The kindness of friends, but above all the energy and devotion of the widowed mother, lightened the weight of this calamity. The subject of our notice was, at this time, but eleven years of age. His education, already begun at the academy under his father, was continued there under his successor, Rev. Samuel Aaron, and for a short time at the once noted school of John Gummere, Burlington, N. J.

The bright and studious mind of Mr. DuBois gathered every advantage from his opportunities, and although his early education did not extend beyond the schools named, he was well furnished in the classics and mathematics and in English literature. While yet a boy he developed a freedom and capacity as a writer quite remarkable; was a frequent contributor of articles to the county papers, and aided in conducting one of them.

His oldest brother was an eminent member of the bar, and it seemed fitting that Mr. DuBois should, under his guidance, adopt the law as his profession. He accordingly pursued the usual course, in the meantime aiding to support himself by literary work and conveyancing, and was admitted to practice in September, 1832. But it was not permitted him to prove whether he could attain reputation in that line. His course was arrested by a fatal obstacle. Always somewhat delicate in constitution, he was at this time attacked by a bronchial disorder, which adhered to him through life. It so far affected his voice as to unfit him for the legal profession, or any other requiring him publicly to address his fellow-men. To all human apprehension this was a calamity that dashed every hope of eminence, at least in any intellectual field. But as we now stand at the end of his career and review the steps by which he gained distinction, we rather persuade ourselves that it was a providence constraining him to a course of life in which every higher quality of his mind and character had

full play, while the physical affection, if it caused to himself some suffering, in no degree hindered his success. For since a change of profession had become necessary, he accepted an appointment in the Mint at Philadelphia, and thus began the life-work by which his reputation was established and made firm.

Mr. DuBois entered the Mint in September, 1833, and was first employed in the office of the Director, Dr. Moore. In 1835, at the request of the Assayer, Mr. Jacob R. Eckfeldt, he was transferred to a more congenial position in the Assay Department. Here he continued for the remainder of his life. In 1836 he was appointed Assistant Assayer. In September, 1872, he succeeded Mr. Eckfeldt, as Assayer, and remained at the head of the department until his death, July 14, 1881, thus completing nearly forty-eight years of Mint service.

For the special branch of metallurgy in which Mr. DuBois thus engaged, we see that his previous training had not prepared him; but doubtless he had been marked as having the intelligence, the carefulness and the concentration of mind required for this work, and he had in Mr. Eckfeldt, as instructor, a thorough master of the art. It is certain that Mr. DuBois early took rank as an accomplished assayer, and long before his death had reached the head of his profession.

I have referred to the association of Mr. Eckfeldt and Mr. DuBois, and it is fitting, before I proceed farther, to allude to the singular partnership in the labors of these two. The close intimacy made needful by their official relations, developed into warm friendship. The tie was made closer by the marriage of Mr. DuBois, in 1840, to Susanna Eckfeldt, the sister of his chief. I shall have to speak of published works and scientific communications appearing under the names of Eckfeldt and DuBois. Although it was understood that Mr. DuBois was the sole literary author, yet no separate claim of authorship was made by either. Whatever of reputation was earned, each was contented that it might be shared by the other, and jealousy never for a moment weakened a union that bound them for life.

A variety of circumstances gave importance to the Assay Department of the Mint during the service of Mr. DuBois. Most of these he has himself, in rapid summary, and with engaging style, set before us in his obituary notice of Mr. Eckfeldt read before this Society. Considering how intimately he was associated with his chief in the labors of that time, the details thus given were in large part auto-biographical, and I shall briefly recall them as appropriate to this obituary notice.

In the year 1834, a change took place in the ratio of gold to silver in the standard of U. S. coins, the effect of which was to bring large deposits of gold to the Mint. The coinage previously had been chiefly of silver. The more equal supply of the precious metals gave active employment in the assay of each of them; and was of course most valuable as an experience to Mr. DuBois, who about this time became connected with the Assay Department.

In 1837, on a revision of the Mint laws and standards brought about by

Dr. Robt. M. Patterson, then Director, a reform was effected in the method of reporting assays, the millesimal system taking the place of the time-honored but cumbrous method of carats and grains. About this time, also, the older plan of assaying silver was abandoned, the humid assay being substituted, and largely worked under the direct supervision of Mr. DuBois.

About 1838, Branch Mints were organized in the States of Louisiana, Georgia and North Carolina. The labors and responsibilities of the Philadelphia assay department were increased by this development, partly from the necessity of instructing assayers for the new branches, and partly in testing the correctness of the assays made there.

In 1848, the great discovery of gold in California was made known. This brought a tremendous pressure on every department of the Mint, and not the least on the Assayers. The gold coinage was in three years raised from a little over three million dollars to more than sixty-two millions. The assays were often counted by hundreds in a day. But whatever the pressure in the office, accuracy ruled, and the correctness of the assays was never impeached.

In 1853, a change was effected in the law for providing subordinate silver coins. This brought about, for some years succeeding, an unprecedented coinage of that metal, and still further increased the labors of the Assay Department.

Shortly after, a minor coinage, in part of nickel, was established, and the assay of that metal became a part of the routine of the deparment. The determination of nickel alloys was not well laid down in the books, and the assay was troublesome, but all difficulties were overcome, and a practical method introduced. A bronze coinage afterwards followed, calling for further assay processes.

Finally, and after Mr. DuBois became principal Assayer, in 1872, followed the heavy coinages of gold as a consequence of the Resumption Act, and of silver under the Silver Act of 1878. These, while they brought heavy labor and responsibility on the Assay Department, involved nothing new in the methods, and only served to test the accuracy and system of the office while placed in his charge.

This review points to the occasions, connecting Mr. DuBois most directly with the Mint by his official action. But he was not content with the performance of routine duty. More than once he has quoted as a rule of action a saying of Paley, that "a life without employment is a life not worth living." He was, indeed, never idle. We might infer that the harassing labors of an Assayer would prove sufficiently absorbing. Yet not long after he entered the Assay Department, Mr. DuBois found, or made, the time for engaging in other tasks.

One of these was the foundation of the Cabinet of Coins which now adorns the Mint. This was commenced in 1838. A small annual appropriation was procured from Congress for this purpose, and the work of collection committed entirely to Mr. DuBois. He brought to it all the

enthusiasm which animates most numismatists, sobered, however, by good judgment. His expenditures were always judicious. Some of the best of the specimens were culled from the Mint deposits for the bullion value merely of the pieces. After the collection had taken good shape, and been well classified, he wrote and published in 1846, a description of it, under the title "Pledges of History," &c. The title thus selected intimated his opinion as to the real value of such collections. He thought that a coin should be prized for its historical teaching, or artistic merit, and discouraged the rage to possess a piece simply because of its rarity. Mr. DuBois acted as Curator of the Cabinet until his death. It falls short of many other collections in numbers, but is so well selected and arranged that it holds high rank in the estimation of good judges. The study of numismatology thus begun in his youth he continued to the last, and was ranked as among the chief masters of the science in our country. He added to it a special study of counterfeits, in the detection of which he became an expert, and was able to give much valuable information to the public.

Another important labor undertaken by Mr. DuBois (in connection with Mr. Eckfeldt) was the preparation and publication, in 1842, of a "Manual of the Gold and Silver Coins of all nations, struck within the past century." This was a work of very great labor, and, from its expense, of some risk also, to the authors. It is admirably arranged, the information clear, and it embraced every subject of interest at that date as to coins, bullion, counterfeits, &c. Subsequently, in 1850 and 1851, supplements were published covering later topics, made prominent in consequence of the California gold discoveries.

Apart from the above more ambitious works, the occasional writings of Mr. DuBois were numerous, and continued up to the year of his death. His papers on Numismatics were frequent and always attractive, his last appearance in print being in April of this year, in an article on "The Coinage of the Popes." To the "American Philosophical Society" of which he was elected a member in 1844, he made various communications, on behalf of Mr. Eckfeldt and himself, mostly on topics suggested by experiences in the Assay Department. Among the most curious was one on "The Natural Dissemination of Gold," by which we were astonished to learn that this precious metal is found in appreciable quantity in the clays underlying our city.

In 1869, he wrote, for the Banker's Magazine, "Propositions for a Revised System of Weights, and a Restoration of the Silver Currency." The development of his views on these subjects is a model of clear exposition, and the conclusions reached were such as might be expected from a mind aiming to attain practical results rather than to impose visionary theories. The time may yet come when these views, in whole or in part, will be embodied in legislation.

I refer, with some hesitation, to other writings of Mr. DuBois, since they were privately printed, and carefully reserved from the public eye. These

were Genealogical Records of his father's and mother's families. It has been well said by Daniel Webster, that "men who are regardless of their ancestors and of their posterity are apt to be regardless of themselves. Our ancestors belong to us by affectionate retrospect; our descendants by affectionate anticipation." Some such sentiment must have encouraged Mr. DuBois in the labor involved in the preparation of these Records. They were written with perfect good taste and truthfulness, and set a good example in a branch of literature then novel, but in these latter days not uncommon.

I have now traced the principal occasions bringing Mr. DuBois before his fellow-men, but cannot bring this notice to a close without referring to some other particulars, bearing upon his character as an officer and a man.

From the beginning he was highly esteemed at the Mint. It was his ambition to acquire a knowledge of every branch of the service, and with his capacity and opportunities this end was attained. He early became the trusted friend and counsellor of his colleagues, and was able to serve them in many ways, perhaps most of all with his ready pen. As time passed, and forty-eight years of experience was given to him, he was recognized by all as the Nestor of the Mint service.

And here I pause to draw a lesson, from the example of Mr. DuBois's life, as to the value of a properly organized civil service. In the department with which he was connected, political tests were never obtruded, and permanence of tenure followed on merit. On no other basis could his services have been claimed or retained. They would have been transferred to a private sphere, probably to his pecuniary gain, certainly to the public loss. Under a more rational policy, he was content to give to the Government the devotion of a life-time. Proud of the service in which he was engaged, he sought to fix it at a high standard. If he lent it reputation by his labors and varied talents, he felt that this was for himself a sufficient reward. And he sought further to elevate the service through the new men brought into it, giving to their instruction an intelligence and patience which they gratefully remember. But if he spared not himself, and gave freely of his time, his talents, and his experience, he was nevertheless sparing for the Government, cautious in public expenditure, scrutinizing the smallest details, and never permitting an extravagance.

We have seen that Mr. DuBois appeared on many occasions as an author. It is to be regretted that these were not more frequent, for his style had singular merit. Whatever was the matter treated, he attracted and held you to the end. There was a certain quaintness, a vein of humor, which cropped out in the most unexpected way, and all the more charming from the contrast with the otherwise dry theme under discussion.

In personal appearance Mr. DuBois was tall and spare, showing marks of the delicate health to which he was subject from early manhood. His features were regular, his eyes dark and brilliant, his countenance habitually grave, but easily lighted to kindly expression in the intercourse with friends. He was deterred by the vocal difficulty, of which I have spoken,

from seeking society, but he enjoyed it when it came in his way, was a good listener, observant, and with a keen sense for the humorous side of things. He was very accessible, and ever ready to lend aid from the stores of his knowledge, but in particular did he delight to instruct and bring forward his younger friends.

I am happy to close this notice by speaking of the deep religious faith of this dear friend. Before reaching manhood, he consecrated his life to the service of God, through Christ, and never afterwards wavered in his trust. His belief was to him a source of perennial joy, and he did not fail in the duty of trying to bring others to share in the faith which was the life of his life. No stress of labor, no ordinary worldly interests, checked the spiritual meditations of this earnest man. Since his death there have come to light, before kept secret from his own family, volumes covering a period of nearly fifty years, embodying mainly his religious thoughts, and laying bare his soul. I confess that it is with a certain awe that I have read these utterances, voiced as it were from the grave. Here the whole man is seen, and the completeness of his character made clear.

Mr. DuBois was able to fulfill his official duties until within a few months of his death. He was fully conscious of his approaching end, preserving his intelligence to the last, and the faith which had comforted him in this life supported him at its close. He left surviving him a widow, two sons, and one daughter, who have in the memory of his well-spent life a blessed inheritance.

Note on the Laramie Group in the vicinity of Raton, New Mexico. By John J. Stevenson, Professor of Geology in the University of the City of New York.

(*Read before the American Philosophical Society, December 2, 1881.*)

Raton, New Mexico, is an important station on the Atchison, Topeka and Santa Fé Railroad, at about five miles south from the Colorado line. It stands on the Canadian plain immediately south from the basalt-capped Raton plateau (the Chicorica mesa of Hayden's map of Colorado), and at the foot of the Laramie bluff, which forms the western boundary of the plain. The cañon of Willow creek, followed by the railroad from the Colorado line, opens at little more than a mile north from Raton. Dillon's cañon and that of the Upper Canadian open together at barely two miles south-west from the station, while petty cañons notch the face of the bluff at irregular intervals.

The lower beds of the Laramie group are fairly well shown at many places along the bluff as well as near the mouths of the larger cañons. During 1881, the Atchison, Topeka and Santa Fé Railroad Company made extensive examinations of the *Dillon coal bed, coal bed A* of the writer's generalized section, which exhibit the structure of the bed far better than

did the natural exposures described in the writer's report on his explorations of 1878.* The measurements made at the company's openings are given here as supplementing the observations detailed in that volume.

The *Dillon* is the lowest persistent *coal bed* found in the Trinidad coalfield, and is separated from the *Halymenites sandstone*, by but five to ten feet of shale. An opening on Coal cañon, tributary to that of the Upper Canadian, shows the following section:

1. *Coal*	0′ 3″ to 8″		
2. Shale	3′ to 4′ 0″		
3. *Coal*	0′ 8″		
4. Shale	0′ 1″		
5. *Coal*	0′ 6″		
6. Shale	0′ 1″		
7. *Coal*	0′ 7½″		
8. *Coal* and sandy clay	0′ 4½″		
9. *Coal*	0′ 6″		5′ 1″
10. Shale	0′ ¼″ to 4″		
11. *Coal*	1′ 3″		
12. Shale	0′ 1″ to 4″		
13. *Coal*	0′ 10″		
14. Bony *coal*	0′ 4″		

No. 3 sometimes falls to 4 inches. Like No. 5, it contains some good coal, but with it is not a little bony stuff, and the whole is strongly pyritous. Nos. 4, 6 and 12 are hard pyritous clays. Nos. 8 and 10 are sandy, sometimes becoming hard sandstone. Nos. 7 and 9 are fairly good coal, but contain binders and diagonal streaks of sandstone, which make them utterly worthless. Nos. 11 and 14 are bony stuff, but No. 13 is excellent coal.

This opening is evidently on the upper division of the bed. The lower division is not exposed. Another opening was run in the Canadian cañon, where entries had been driven in both divisions of the bed. The lower division has five benches, all of which yield coal with much ash. No new features were seen in the upper division. The clay overlying the bed here is full of leaf impressions.

A section was obtained in Dillon's cañon at a deserted opening, just below Dillon's ranch. This is described in the writer's report† upon this region, but the measurements are repeated here to show the general structure of the bed. The section is:

Upper division		4′ 4″
Carbonaceous shale	0′ 4″	
Coal	2′ 10″	
Shale	0′ 4″	
Coal	0′ 10″	

*U. S. Geographical Survey, west of the 100th Meridian, Vol. III. Supplement. Now passing through the press.

†Loc. cit. p. 275.

Clay shale, drab		2′ 8″
Lower division		4′ 7″
Coal	0′ 10″	
Parting	– —	
Coal	0′ 8″	
Parting	– —	
Coal	1′ 7″	
Clay	1′ 0″	
Coal	0′ 6″	

The outcrop coal is not altogether promising in appearance, and has a decidedly slaty structure. Some of it was tried on a locomotive, but it burned much like rotten wood. Prospecting entries were driven into the sound coal at a little way below the old opening. The quality improved rapidly as the entries advanced, and a locomotive test of the sound coal proved as satisfactory as that of the crop coal had proved unsatisfactory. Extensive mining operations were begun here in June of 1881.

Many prospecting pits were digged north from Dillon's cañon along the bluff fronting on the plain, but none of these reached sound coal.

Fulbrite & Company made an opening in the *Dillon coal bed*, at, say, a mile and a half north-west from Raton. They mined only the upper division, which has the following structure:

1. *Coal*	0′ 11 ″		
2. Sandstone	0′ 0¼ ″		
3. *Coal*	1′ 1 ″		
4. Parting	0′ 0¼ ″	4′ 1½″	
5. *Coal*	0′ 8 ″		
6. Parting	0′ 0 1/16″		
7. *Coal*	1′ 5 ″		

The coal of Nos. 1, 3 and 5 is compact, though in part of slaty structure, and is an excellent fuel. The ash is bulky but powdery. No. 7 breaks much like cannel, and in appearance is fully equal to some of the Pennsylvania cannels which are thought to be good marketable coals. It gives a long quick flame, and yields a bulky, powdery ash. This bench is sometimes parted near the middle. The lower division of the bed is not well exposed, but as nearly as can be determined, its thickness is 30 inches near the mouth of this pit.

An opening near the mouth of Willow creek cañon showed:

1. *Coal*	0′ 11 ″		
2. Parting	– —		
3. *Coal*	0′ 10 ″		
4. Parting	– —		
5. *Coal*	0′ 7½″	3′ 7½″	
6. Parting	– —		
7. *Coal*	0′ 6 ″		
8. Parting	– —		
9. *Coal*	0′ 9 ″		

This also is on the upper division, and the features are very similar to those observed at the Fulbrite opening. At the time of examination, the entry had been driven 79 feet, but sound coal had not been reached as the hillside is very badly slipped. Another opening was run at a little distance further up the cañon. There the lower division is insignificant, and an entry had been driven nearly 60 feet in the upper division, which showed :

1. *Coal*	0′ 6″ to 8″	2′ 11″ to 3′ 7″
2. Sandstone parting	0′ 1″ to 2″	
3. *Coal*	0′ 7″	
4. Clay and sandstone	0′ 1″ to 2″	
5. *Coal*	0′ 8″	
6. Bony *coal*	0′ 2″ to 3″	
7. *Coal*	0′ 5″	
8. Bony *coal*	0′ 1″ to 2″	
9. *Coal*	0′ 4″ to 6″	

The quality of the coal varies materially in the several benches. It all burns readily, and yields a powdery ash. No. 7 and 9 are liked for use as domestic fuel. At another opening further up the cañon, the lower division is worthless, and the mining was done on the upper division, which shows :

1. *Coal*	0′ 6½″	2′ 11½″
2. Parting	– —	
3. *Coal*	0′ 6″	
4. Parting	– —	
5. *Coal*	0′ 6 ″	
6. Parting	– —	
7. *Coal*	0′ 8 ″	
8. Parting	– —	
9. *Coal*	0′ 9 ″	

Unlike the other pits, this shows no good coal, and the whole bed is more or less bony. The last opening examined is at nearly two miles from Raton, and very near the last exposure of the bed in this cañon. No exposure of the rocks, either above or below the bed, was found, but the structure at this opening is so different from that observed at the other pits, that there is no room for doubting that this is the lower division. The section is :

1. *Coal*	0′ 4½″	3′ to 2′ 10½″
2. Shale	0′ 2½″ to 4″	
3. *Coal*	1′ 3 ″ to 9″	
4. Shale	0′ 5 ″ to 8″	
5. *Coal*	0′ 9 ″	

No. 1 burns well, but is very bony, and the ash consists of angular frag-

ments. No. 3 leaves a powdery ash, but it is pyritous. Nos. 2 and 4 vary at its expense. No. 5 is merely a coaly shale. The roof is irregular, and rolls or horsebacks cut out much of the bed.

The coal from the *Dillon bed* is far from being such as is obtained from the standard beds of the Appalachian field, but it is fully equal to that from many beds, which is used as domestic fuel over large areas of our country. That from the openings in Dillon's cañon, from Fulbrite's opening and from one opening in Willow's creek cañon is a good domestic fuel, superior indeed to that from the *Waynesburg coal bed* in Southwest Pennsylvania, which is an important source of supply for an extensive area. The ash does not exceed 15 per cent., barely one-half more than the amount contained in much of the Connellsville coke. This bed will become important to the region along the Atchison, Topeka and Santa Fé Railroad, which is cut off from the *Trinidad bed* at Trinidad, by the difficult grade between Trinidad and Raton pass.

Another bed, probably *coal bed H* of the writer's generalized section, has been mined to some extent near the head of Willow creek cañon. The bed was opened somewhat more than a year ago by Mr. Pettigrew, who hauled the coal to Raton. The section at the Pettigrew opening is:

1. *Coal*	1′ 0″		
2. Shale	1′ 0″		
3. *Coal*	2′ 2″		
4. Sandy shale	0′ 1½″		5′ 10″
5. *Coal*	0′ 10″ to 8″		
6. Sandy shale	0′ 1″		
7. *Coal*	0′ 8″		

No. 1 is slaty, and streaks of coal occur in No. 2. The coal from No. 3 is clearly the best found within several miles of Raton. It leaves a somewhat bulky ash and contains some pyrites, but it is a strong fuel, and admirable for steaming, as has been proved by tests on locomotives, where it worked better than the Trinidad coal does. It is preferred also for domestic purposes. The coal from No. 5 is but little inferior to that from No. 3, and the two benches were mined. No. 7 yields a coal which is hardly equal to that of the other two benches. The bed is somewhat twisted in this mine. A sudden dip was found at a short distance from the mouth of the pit, which continues for somewhat more than ten yards, beyond which the miners did not follow it.

The railroad company has opened an extensive mine at a little way further down the cañon. The measurements there are almost exactly the same as in the Pettigrew opening.

On a New Substance resembling Dopplerite from a Peat Bog at Scranton. By Henry Carvill Lewis, Professor of Mineralogy in the Academy of Natural Sciences of Philadelphia.

(*Read before the American Philosophical Society, December 2, 1881.*)

In the course of an excavation for a new court-house at Scranton, Pa., made last July, a very interesting substance was discovered, specimens of which were sent to the writer at that time for investigation. The excavation cut through a peat bog, and it was at the bottom of this bog, some 25 feet from the surface of the ground, that the substance here referred to was found.

It appears that formerly there had been a lake or swamp at this place, which with the extension of the town had been filled up. Below eight feet of cinder and other rubbish there is a bed of peat 10–12 feet in thickness. The peat is said to be a good fuel after drying. Beneath the peat is a deposit of "swamp muck" or carbonaceous mud, which dries to a hard compact gray mass, burning with difficulty. In this "muck" are numerous plant remains and occasional seeds.

The whole deposit rests upon glacial till or "hardpan," and is therefore of post-glacial origin.

Scranton is in the glaciated portion of the State, and the peat bog found here is one of the many which owe their origin to glacial causes. These peat bogs have been formed, for the most part, in former swamps or lakes caused by the damming up of streams by ridges of drift deposited at the time of the melting of the glacier.

Near the bottom of the Scranton peat bog are irregular veins filled with a black jelly-like substance, elastic to the touch. The veins of this substance, which are confined to the muck above described, vary in width from a mere stain to between two and three inches, and make all angles with the horizon, being frequently nearly perpendicular.

The substance, as thus found, has the following properties: When first taken from the ground it is jelly-like in consistency, breaking with a conchoidal fracture, and having a hardness of less than 1. Immediately on exposure to the air it becomes tougher and more elastic, resembling India rubber. It may be preserved in this condition if kept in alcohol. The substance is black by reflected light. When a thin slice cut by a knife is examined under the microscope it appears brownish-red by transmitted light, and is nearly homogeneous in character.

Occasional seeds occur in this substance as well as in the surrounding peaty matter. In general appearance they resemble the seeds of certain Cyperaceæ. Under the microscope their surface is seen to be curiously marked with irregular wavy outlines. Professor J. T. Rothrock has been kind enough to make some sections of these seeds and reports concerning them that they have the characters of spores of one of the higher cryptogams, probably *Marsilia*. He states that Marsilia is a bog plant which is found during later geological time, and that the general shape and size of

its fruit corresponds with that of the specimens under examination. The outer coat is made up of outwardly pointing prismatic columns, the extremities of which gives the peculiar wavy appearance seen on the surface of these *peat seeds*. Yet since the interior bag and its contents can be reduced neither to an embryo nor to the interior structure of the Marsilia, it is not possible to assign these seeds definitely to that species. No other recognizable organisms have been noticed in the substance here described.

The black jelly is tasteless and odorless. If placed in the flame of a Bunsen burner before drying, it burns slowly and without flame. It is almost insoluble in water, alcohol or ether, but is almost completely dissolved in caustic potash; and from the dark-brown solution thus formed may be precipitated in reddish-brown flocculent masses by the addition of an acid.

After exposure to the air until completely dry, the substance becomes brittle, and nearly as hard as coal. In this condition it resembles jet or some of the varieties of lignite, and might readily be mistaken for those substances. It acquires a hardness of 2.5, and has the brilliant resinous lustre, and conchoidal fracture of true coal.

It has a specific gravity of 1.032. It is jet black in the mass, but in powder is dark-brown. It now burns with a clear yellow flame. Soaking in water will not soften it appreciably. In the closed tube it gives off water, and abundance of brown oil and empyreumatic vapors. The latter are in the form of a white smoke which can be lighted at the end of the tube.

In solubility it is like the undried substance. Hot alcohol dissolves a small portion, and forms a pale yellow solution. On treatment with caustic potash it dissolves completely, with the exception of an extremely slight residue of impurities. It will dissolve even in the cold. This test serves to distinguish the dried substance from brown coal or lignite, which are but partially soluble in alkalies.

A very slight trace of ammonia is given off on heating with caustic potash. By dissolving in a standard solution of alkali and titrating with standard acid, it is found that the substance has an acid reaction. It is therefore either an organic acid or a mixture of such acids.

The physical characters of this substance are closely allied to *Dopplerite*, but its chemical composition, as will be seen from its analysis, prove it to be an undescribed substance.

Mr. John M. Stinson, of the Second Geological Survey of Pennsylvania, has, at the request of the writer, kindly made the following analysis. The substance was carefully separated from the surrounding earthy material, and dried at 212° F. before analysis. Carbon and hydrogen were determined in duplicate, the two determinations closely agreeing:

Carbon	28.989
Hydrogen	5.172
Nitrogen	2.456
Oxygen	56.983
Ash	6.400
	100.

Approximate analysis of the dry separated material gave :

Volatile matter	72.190
Fixed carbon	21.410
Ash	6.400
	100.

Subtracting the amount of ash from the first analysis, we have :

C	30.971
H	5.526
O + N	63.503
	100.

From this we may deduce the empirical formula $C_{10}H_{22}O_{16}$. This formula would yield the calculated composition :

C	30.15
H	5.53
O + N	64.32
	100.

In giving the above formula, it is by no means assumed that it represents a simple mineral substance. It is merely a convenient expression of its composition. It is probable that the substance here described is a complex organic acid containing water. The nitrogen may possibly exist as ammonia. The small amount of carbon and the excess of hydrogen distinguish this substance from other organic acids. By the subtraction of NH_4O, and one or more parts of H_2O from the formula, it may be more closely allied to some of the organic acids which form Humic acid, the formula of which is so variously given by different authors. The determination of the true formula of the acid here analyzed, can only be determined after the formation of an organic salt with lead or silver. The absence of any exact knowledge concerning the composition of the organic acids existing in humus, as recently shown by Julien,* renders it difficult to express definitely the chemical relations of the substance under discussion.

The relation which it bears to its nearest ally, Dopplerite, may best be seen after a review of the facts as yet gathered about that curious mineral.

The mineral known by that name, and generally-regarded as allied to Humic acid, was first found in a peat-bog near Aussee, Austria, at a depth of 6 to 8 feet below the surface. It was a black gelatinous substance, known by the peat-cutters as "*Moder-substanz*," which after exposure to the air became at first elastic and afterwards brittle, assuming the lustre of coal. Döppler drew attention to this substance in a paper entitled "On a re-

* Proc. A. A. A. S., 1876 p. 311.

markable gelatinous substance discovered in Austria," read before the Vienna Academy in 1849,* and stated that it was nearly insoluble in water, alcohol and ether, but almost entirely dissolved by caustic potash.

Having been referred to Haidinger and Schrötter for further examination, it was fully described and named by them a week later. Schrötter† found its composition to be (after drying at 212° F.):

C.....	48.06	or without ash	
H.....	4.93	C.....	51.63
O.....	40.07	H.....	5.34
N.....	1.03	O + N...	43.03
Ash.....	5.86		

Haidinger named the substance and described its physical properties. He stated the observation of Löwe that it burned without flame, and that of Ettinghausen that it contained recognizable vegatable organisms.

In 1858, Gümbel‡ announced that a substance very similar to Dopplerite occurred in a peat-bed near Berchtesgaden, Bavaria. Like the substance from Scranton, a black jelly-like substance was found as irregular and sometimes nearly vertical veins of varying, but slight thickness, in the lower part of the peat. It was known as Peat-Pitch-Coal. It was very slightly soluble in alcohol, giving it a pale yellow color, but was almost completely soluble in alkali. Unlike the original Dopplerite, it burned with a yellow flame. Gümbel indicated the chemical changes which converted wood into peat, and showed that Dopplerite had the same composition as peat, and was in fact a truly homogeneous peat.

In 1863, Dopplerite was discovered in a peat-bog at Obburg, Switzerland, and was described by Kauffmann, who in an important paper§ showed that it had the same physical properties and chemical composition as the Dopplerite of Aussee.

It occurred in a black peat at a depth of 12 to 14 feet, in layers sometimes a foot in thickness. Except in burning without flame, its physical properties were nearly identical with the Scranton substance. The air-dried Dopplerite lost 19.7 per cent. of water at a heat of 110° C., and according to Muhlberg had the following composition:

C.....	52.2
H.....	5.9
O + N.....	35.7
Ash.....	5.2
	100.

By dissolving in caustic potash, precipitating by acid, and then analyzing the dried precipitate, a similar composition was obtained. Kauffmann

*Sitzunsb. d. k. Acad. d. Wiss. Wien, 1849, Vol. i, p. 239.
†Loc. cit. p. 286.
‡Neues Jahr., f. Min., 1858, p. 278.
§Jahr., d. k. k. Geol. Reich, Wien. 1865, Vol. xv, p. 283.

concludes that Dopplerite consists of one or more of the humous acids, and shows that the portion of peat soluble in alkali is identical with Dopplerite, and that compact peat contains minute black particles of Dopplerite. Peat is therefore a mixture of Dopplerite with partially decomposed plant remains; while Dopplerite itself may be regarded as a homogeneous peat in which all organisms have been decomposed. He shows that in different peats the proportion of Dopplerite, or part soluble in alkali, increases with the age of the peat, while the contrary is the case with mineral coal. Thus while in a recent peat but 25–30 per cent. was soluble, in an old compact peat, the proportion was 77 per cent. On the other hand, the solubility of coal, decreases with its age, as shown in the following table, where the figures represent the degree of solubility in alkali:

(Dopplerite)	(100)
"Slate coal," a woody lignite, Diluvial	75
Brown coal	42
"Pitch coal." Upper Miocene	10
" Lower "	5
Bituminous coal, Eocene	2.3
" " Carboniferous	trace.
Anthracite	0

He concludes that in the formation of coal from peat, the first step of the process is the formation of Dopplerite, and the second the gradual transformation of the latter into a material less soluble in alkali, and richer in carbon.

Several other European localities for Dopplerite have more recently been discovered.

A substance resembling Dopplerite in the peat of Hägnetswyll, St. Gall, Switzerland, mentioned by Deicke,* burns with flame, and is regarded by Kenngott as having characters more nearly approaching those of Pyropissite or Melanchyme. It possibly is more analogous to the substance from Scranton.

Dopplerite has not as yet been discovered in America. While the substance described in the present paper more nearly resembles Dopplerite than any other known mineral, it differs, as already shown, both in composition and in its behavior when burning.

A distinguishing feature of the Scranton mineral is its very low percentage of carbon. Dopplerite has almost the precise composition of peat, and peat, as is well known, contains more carbon than is contained in wood. Yet the Scranton mineral contains even less carbon than is contained in wood.† The empirical formula of the Scranton mineral gives

*Neues Jahr. f. Nim., 1858, p. 663.

†The composition of peat is about:

C	H	O + N	Ash.
61	6	33	= 100

The average composition of wood is:

C	H	O + N	Ash.
49.6	6.1	43.1	1.2 = 100

v. Coal, its History and Uses. Thorpe, etc., p. 165.

a larger amount of hydrogen than is expressed in the formulas of any similar substance.*

The first printed notice of this substance was given by Mr. T. Cooper.† A week later Mr. C. A. Ashburner, contributed to the same Journal the following analysis made by Mr. J. M. Stinson:

Water at 212°.....	66.758
Volatile matter.....	9.826
Fixed carbon	4.012
Ash.....	19.404
	100.

Mr. Stinson informs the writer that this analysis was made upon a sample consisting of a mixture of peat, muck, and the jelly-like substance, and that as no attempt was made to separate the latter, the analysis is not of scientific value.

Special interest is attached to the substance here described as being perhaps an intermediate product between peat and coal. While the quaternary lignites illustrate the transformation of wood with coal, this substance illustrates a similar change from peat. As by the investigations of Kauffman, it was shown that the formation of Dopplerite preceded that of any of the varieties of coal, so in the present case we have perhaps a yet earlier stage.

The characters of the Scranton mineral entitle it to a distinctive place among the hydrocarbons of natural origin. It has been the custom among mineralogists to regard these substances, as mineral species. In view, however, of the objection to adding new mineral species whose distinctive characters are made prominent only by analysis, the writer believes that it would be more advisable to combine those already described under generic names, and to regard the minerals included in such genera as varieties.

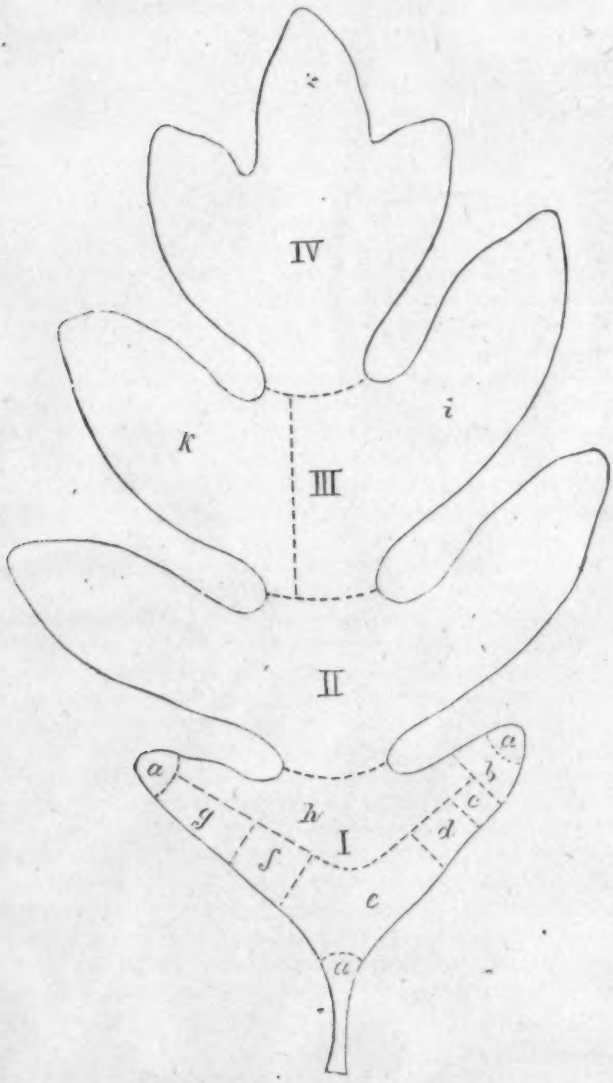
In the present case we have to do with a black jelly-like substance derived from vegetable decomposition, which with a different composition and with somewhat different physical properties has been found in similar geological conditions in several parts of Europe. It is therefore suggested that all of these substances be combined under one generic name. The name "*Phytocollite*" (*φυτόν, κόλλα*) signifying "plant-jelly," would include all jelly-like substances formed by the decomposition of plant matter. Dopplerite would then be regarded as one of its varieties, the mineral described by Diecke would be another, and the mineral from Scranton yet another.

* The formula of Dopplerite has been given as:

C_{40}	H_{35}	O_{25}	(Gmelin);
C_{16}	H_{10}	O_{10}	(Descloiseaux);
C_{10}	H_6	O_5	(Dana).

† Engineering and Mining Journal, Aug. 13, 1881.

PLAN OF ROCKERY



ON THE CAMPUS OF THE UNIVERSITY OF PENNSYLVANIA.

Rockery at the University of Pennsylvania, built in 1881. By Eli K. Price.

(*Read before the American Philosophical Society, Dec. 16, 1881.*)

The form of the White Oak leaf is used and the rocks so placed, that every one may be seen. They are arranged according to the places where they were found, to show how nature has disposed of them.

SECTION I.—The large upright black stones at the three corners (*a*) came from the tunnel on Thirtieth Street, near Master, 40 feet below the curb, 50 to 60 below the gravel hill.

The quarried stones (*b*) are from the quarry of Price & Moore, next westward of the Woodlands Cemetery; those next east (*c*) from the quarry of Samuel C. Bunting, Junior, south of Walnut, west of Forty-fourth Street; those farther east (*d*) from William P. Supplee's quarry east of Fifty-third Street, southward of Girard Avenue; those marked (*f*) from McKinley's quarry on Rittenhouse Street, near the Wissahickon; and all the other quarried stones in this section (*e* and *g*) are from grounds of Eli K. Price, on both sides of Twenty-ninth and Thirtieth Streets and of Master and Jefferson Streets; and the residue of this section is covered by transported rubbed rocks from the gravel hills of the same and adjoining grounds, at an elevation of about 100 feet.

SECTION II is wholly covered by white and light-colored rocks, transported and polished, from grounds of George S. Harris, J. Clothier, L. Dolby and others, on south side of Market Street, from Forty-eighth to Forty-ninth Streets, a space of 480 feet by 246 feet, from a sand and gravel hill of a height of about 100 feet above tide. The large white rocks at the ends of this section lay near together, and show that when transported they came as one rock.

SECTION III.—Letter *i* are stones from the south side of Chestnut Street, extending from Forty-seventh to Forty-eighth Streets, from a gravel and sandy elevation of about 70 feet above tide, from the grounds of the Byvam heirs and others.

SECTION III.—Letter *k* are stones from both sides of Forty-fifth Street and of Spruce Street, from grounds of Albert S. Letchworth and others. The elevations were about 90 feet above tide.

SECTION IV is wholly covered by stones from the City Almshouse grounds, westward of Thirty-seventh Street, and both sides of Spruce and Thirty-eighth Streets, from gravel about 85 feet above tide.*

* These elevations are based upon the following *curb heights*, which are about ten feet lower than the gravel banks had been:

PHILADELPHIA, December 8th, 1881.

Dear Sir:—The following are the elevations of the *curb* corners above tide, asked for in your note of 7th inst.:—Jefferson and Twenty-eighth, 96.57 feet; south side of Market and Forty-ninth, 88 feet; south side of Chestnut and Forty-seventh, 64.74 feet; north side of Spruce and Thirty-eighth, 76 feet, and south side ditto, 75 50 feet; Spruce and Forty-fifth streets, 83.50; Tunnel, Thirtieth and Master streets, 40.70 to bottom.

Yours, &c.,

SAMUEL L. SMEDLEY, Chief Engineer and Surveyor.

TO ELI K. PRICE.

For the taking of the above stones I had, as far as known, the permission of the owners or their representatives, and for them the University of Pennsylvania and citizens owe thanks to the City of Philadelphia, to William Baldwin, Chief Commissioner of Highways, George S. Harris, Dr. Twaddell, J. Clothier, L. Dolby, Samuel C. Bunting, Jr., Albert S. Letchworth and others, who gave them these valuable objects of curiosity and science without charge. The hunting, hauling and building them into a Rockery has been my occupation, with men and carts taken from my quarry for one day or more of the week, from the beginning of June to the end of December, 1881. The purpose of gathering these rocks has been for their preservation, and convenience of study by professors and students, and all interested in the important questions to which they give rise.

What do these rocks say to us here to-day? Plainly they show the minerals they contain. But we go back from these to the period of primary rocks, to the granites and other igneous rocks, whose melting and moving power was fire, and whose disintegrations furnished the material for the stratified rocks deposited by later pervading waters; and these also again, becoming disintegrated by frost, heat and water, also became modifying and different sources for their last granular depositions in strata. We have here from the quarries gneissic rocks, the first strata of the secondary formation; and we have the transported rocks, also deposited by water, consisting of materials that have undergone many changes of stratification and re-stratification as well as of attrition.

In the study of these rocks we pass from a time when no life was on this globe into periods since the beginning, spoken of in the first verse of Genesis, wherein all life has been created; and therein perceive the methods of the Creator in the structure of this globe.

The transported rocks demand special explanation. We ask to know what are their compositions? What their names? Where were they in the regular order of the geological stratification? Where geographically? How were they torn from their places? How transported to where found round our University? How polished? How lifted upon the hills? Had we really a great "continental glacier" to bring them here? Was the world made, peopled, civilized for the repetition of the disaster of the "Great Glacier"?

These are some of the questions for the mineralogists and geologists, in and out of the University, to answer: it is hoped that they may long incite to interesting and useful study. The objects are the oldest, but the questions are of new presentation.

Charles E. Hall, of our State Geological Survey, began to observe some of these rocks in 1875, and has partially answered the above questions, according to his observations and convictions at that time. (See Proceedings Amer. Philos. Soc., No. 95, Nov. 1875, p. 633.) He followed Agassiz, Lyell, Geikie, Croll, Dana and Newcomb in placing the south line of the great continental glacier at and below the 40th degree of north latitude,

and naturally inferred that it was the cause of the deposit here of these transported rocks.

In 1878 Professor Cook published his "Report on the Geology of the State of New Jersey," and placed the glacial drift northward, on a line from a point of the Raritan river (lat. 40° 30′), thence N. W. to Denville (near the 41°), thence westward and south-westward to Belvidere on the Delaware (lat. 40° 50′).

In 1881 Professor Henry Carvill Lewis, also of the Second Geological Survey of Pennsylvania, has traced the southern line of the glacial drift through this State for a distance of about 400 miles. He informs me, in advance of publication, that this line, which is marked by a terminal moraine, starts at a point opposite Belvidere, and passes in a north-west direction over the Kittatinny and Pocono mountains, and across the Lehigh and Susquehanna rivers into Lycoming county, where it ascends the Alleghany Mountains, and continues thence in a nearly straight line into Cattaraugus County, N. Y. (lat. 42° 15′). It there curves south-westward and, re-entering Pennsylvania in Warren County, passes south-west through Venango, Butler and Lawrence Counties, until in Beaver County (lat. 40° 50′) it crosses the Ohio State Line.

In his "Essay on the Antiquity and Origin of the Trenton Gravels," Mr. Lewis states his belief as to "the Terminal Moraine" which he had explored, which "winds over hills and across valleys in such a manner that by no other known agency than a great glacier could it have been produced," p. 17. This is the product, he says, of the last glacial epoch. There is some evidence that in an earlier period a glacier advanced south of that limit. To the north "the great glacier has left undoubted traces, in the universal covering of unstratified boulder clay or *till*, in the smoothed and grooved rocks, the transported boulders, &c." "There are many facts which indicate that the ice, even close to its lower terminus, had a thickness of over 1000 feet, which increased northward," pp. 18, 19.

Mr. Lewis also speaks of a post-glacial flood, "at a time when the river [Delaware] was larger than at present," as a "conclusion warranted by many facts, and as a cause of the deposit of the Trenton gravels," p. 19, &c.; and "that the boulders upon its surface were dropped from ice-cakes is, however, probable," p. 23.

Did, then, these transported rocks come here by glacial action? If so, at a first or second glacial epoch? By a great glacier or by floated ice? Were they *lifted* upon the hills by ice or water? Or was the earth sunk when they were brought, and the rocks afterwards lifted by the rising of the earth's surface? Professor Lewis gives to these transported rocks a transporting cause common to the Philadelphia red gravel and our brick clay, at "an epoch of submergence as indicated by the elevation of their deposit;" and that "it is probable that this clay may be assigned to a period when the land stood 150 feet or more below its present level, and

when the cold waters from the melting glacier bore ice-rafts which dropped their boulders," pp. 4, 5, 6, 7.

It seems apparent that the supposed ice-sheets or glaciers have been greatly magnified by the first-named glacialists, both in their thickness and extent, by reason of their taking the earth as a stable land-mark, whereas it is less stable than the ocean. Great rocks have been taken for boulders, though in *situ*, because they have been abraided by floating ice-sheets and the rocks they have borne; rocks supposed to have been transported and *upheaved* by glaciers, have been floated *downwards* by ice rafts or icebergs, and afterwards have been lifted by the rising oscillation of the earth; and mountain sides are supposed to have been scored by great glaciers 6000 or more feet thick, yet the scorings may have been made much lower, and afterwards have been carried upwards to such height by the rising mountains. It seems not to be sober philosophy to seek abnormal causes when the ordinary laws of nature may afford the sufficing explanation. A sufficient cause is enough. The mountain tops have been higher and colder, and been since lowered by erosions; their oscillations have been upwards and downwards; the valleys have been raised by the *débris* of the mountains, and have risen and fallen with the rocks beneath them; and how frequent are these alternations, and for what beneficent purpose, may be seen in every seam of coal in the carboniferous regions; for each was grown on a plain in the open air, and had the light and heat of the sun, and then sank below the waters, that these might deposit the particles to make the protecting covering rocks for the unknown centuries that followed, when again all were corrugated and lifted to bring them into human reach for man's uses, in ages when skillful enough to win and apply the coals, the products of the soil, water, air and sun, and the life that God gave to the plants at a remote and momentous era of creation.

It becomes us not to unreasonably impeach the goodness of the Creator. It seems, from all we know, not likely that He would destine the fairest portion of this earth, where man has best developed his civilization, to destruction by ice. The physical sciences, as well as those of morality and religion, furnish the proof that there is a limitation of forces that conserve nature, and afford us the foundation of a scientific faith that man's best home on earth is an abiding one for the race. Yet must science observe all facts and heed all reasonable reasons; and doing so mankind, it is believed, will gain reassurance that they are held in safety by a Creator who forever conserves His works.

The Vagus Nerve in the Domestic Cat (Felis domestica).

By T. B. Stowell, A.M., Ph.D.

(*Read before the American Philosophical Society, July 15, 1881.*)

The idea of using the cat as the basis of anatomical study is by no means a recent one. Straus-Durckheim's "Anatomie du Chat," Dr. B. G. Wilder's "Anatomical Uses of the Cat," and other papers published by the same author since 1877, and Mivart's recent work on "The Cat," present the general thought with more or less directness. I am not aware, however, that any one has made a study of the nerves of the cat in their detailed distribution. Having compared the vagus nerve in man, cat, dog, horse, ox, sheep, rabbit and frog, I am satisfied that the cat (*Felis domestica*) presents advantages over all others as a basis for comparative study. I accordingly submit the accompanying figures and text to aid students who may be disposed to investigate Comparative Neurology.

The cat, dog, and rabbit were injected with plaster, as recommended by Prof. Simon H. Gage, of Cornell University, in a paper published in The American Naturalist, vol. xii, p. 717. The figures are semi-diagrammatic; they were originally drawn to a scale, natural size; for the purpose of giving prominence to certain relations, to ramuli and anastomotic filaments, such modifications have been made as seemed necessary; where a nerve trunk is continuous, with no distinctive characters, it is shortened, e.g., the gastro-cardiac portions of the vagus (Fig. 9). The figure of the stomach is reduced one-half (Fig. 13). For the sake of simplicity no attempt has been made to reproduce plexuses or the terminal ramification of filaments.

The nomenclature used is largely that advocated by Dr. B. G. Wilder, before the American Association for the Advancement of Science, at Boston, 1880, in a paper entitled "A Partial Revision of the Nomenclature of the Brain," and in a more detailed communication published in Science, March 19, and 26, 1881, entitled "A partial Revision of Anatomical Nomenclature, with especial reference to that of the Brain." The simplicity and perspicuity of the nomenclature commend it alike to the lecture-room and the laboratory.

[In cases where it was thought that any possible doubt might arise from using the new terminology, the new words are followed by their anthropotomical equivalents.]

The vagus nerve (N. vagus; N. pneumogastricus; Pars vaga; Par vagum; N. ambulatorius; N. sympathicus medius; Eighth pair, pneumogastric branch, Willis; Tenth pair, Sömmering and Vicq-d'Azyr) presents the following marked characters, viz:—

General Characters: N. vagus has the most extensive distribution and the longest course of the cranial nerves; in its cephalic region principal rami are derived from ganglia; it forms by its frequent and complex anastomoses with N. sympathicus numerous plexuses, hence presents involved physiological and pathological complications; its terminal fila-

ments supply the muscular substance and the mucous membranes of organs; its development in relation with the development of, notably, the heart and adjacent blood-vessels, and the stomach, renders its distribution somewhat asymmetrical, necessitating special anatomical study of its dextral and sinistral relations, and giving corresponding and distinctive physiological and pathological characters; the relation of this nerve to organic life, to the automatic and the reflex phenomena of respiration, and to the so-called "inhibitory phenomena" gives importance to its study.

Special anatomical characters: N. vagus and its rami are distributed to the most important viscera, at least to viscera most intimately related to the functions of organic life, e. g., *digestive*—pharynx, œsophagus, stomach, liver, pancreas, intestines; *circulatory*—heart, pulmonary arteries, pulmonary veins, systemic arteries and veins in the region of the heart; *respiratory*—larynx, trachea, bronchi, substance of lung.

Special physiological characters: N. vagus is a sensory-motor nerve, having both sensitive and motor fibres; it controls, regulates or modifies the movements and the secretory functions of the organs to which it is distributed, and upon it depend the sensory phenomena which characterize the respective organs.

DESCRIPTION: Origin and cervical portion—N. vagus in the cat (*Felis domestica*) takes its superficial origin from two regions of the medulla: by 12–14 filaments from the ventral border of corpus restiforme and the depression line between cp. restiforme and the portion of medulla next laterad (Fig. 3, 4),* in a line caudad of (posterior to) the origin-filaments of N. glosso-pharyngeus (ninth pair of cranial nerves), (Fig. 2, 4), from which nerve it is sometimes separated by a small arterial twig of A. cerebellosa inferior; and by 4–6 filaments immediately ventrad in the slight depression line ventrad of oliva and cephalad of the origin-filaments of the spinal portion of N. accessorius (Fig. 2. L). The dorsal filaments form a somewhat curved line of superficial origin, measuring 3–4 mm. in caudo-cephalic direction, and presenting its convexity dorsad (Fig. 2. X); the cephalic filaments are most ventral and leave the medulla oblongata just caudad of A. cerebellosa inferior—a considerable branch of A. basilaris at right angles with the main trunk and

* There is some difficulty in establishing satisfactorily the homologies of the medulla. There are reasons for regarding the third nerve tract from the dorsimeson as the homologue of corpus olivarium; this is manifestly not the cp. olivarium of Foster as given in his "Practical Physiology;" it should be noticed that the cephalic origin-filaments of N. accessorius become apparent in this depression line, while the caudal origin-filaments appear along the depression line ventrad of this tract. The elliptical area (Fig. 1, 3) laterad of ventripyramis (anterior pyramid) and the one still dorso-lateral have relations upon which homologies might be based, giving each one the name oliva (corpus olivarium). It is not proper in this connection to discuss homologies. I have made this allusion in apology for the indefiniteness of description of the origin-line of N. vagus. Whatever homologies may be established and names assigned, the figures (Fig. 3, 4) designate the relation.

given off 4–6 mm. cephalad of union of AA. vertebrales. These filaments unite about 1 mm. peripherad of their superficial origin into six or seven ramuli, which lie ventrad of plexus choroideus lateralis (Fig. 2, Pl. Ch.), and blend in foramen jugulare to form a single flattened nerve trunk, N. vagus. In the **passage through the foramen** 6 mm. peripherad of its origin, N. vagus is enclosed in common with N. accessorius (XI) in a sheath formed by a tubular prolongation of the dura mater and the arachnoid membrane, where it is also joined by N. glosso-pharyngeus (IX); but the sheath of the united NN. vagus (X) and accessorius (XI) may be readily dissected from that of N. glosso-pharyngeus (IX), which lies ectad and cephalad. Centrad of its foramen of exit—Foramen jugulare, (Foramen lacerum-posterius, Lacerum foramen posterius)—and 3–4 mm. peripherad of medulla oblongata, N. vagus presents a ganglionic enlargement, **ganglion jugulare,** ganglion of the root. This ganglion is hemispherical in form, of a grayish color, and measures nearly 2 mm. in diameter; it has relations with NN. facialis, glosso-pharyngeus, accessorius and sympathicus (Fig. 5, J).

At G. jugulare, N. vagus is connected by a single twig with the adjacent petrous ganglion of N. glosso-pharyngeus (IX) the "ganglion of Andersch" (Fig. 5, Pe.); by a considerable trunk with N. accessorius (Fig. 6, *10*); by ramus auricularis (Fig. 5, *2*), with N. facialis (VII), from which ramus, a slender ramulus penetrates the petrous bone and joins a branch of N. facialis; a portion of the ramus continues across N. facialis to the cochlea (Fig. 5, *5*), a filament from the auricular branch connects with a ganglionic plexus of N. sympathicus, entad of the gangliform plexus of N. vagus.

Plexus gangliformis. The 5 mm. of N. vagus immediately caudad of G. jugulare is involved in a somewhat intricate net-work, which seems to be allied to plexus gangliformis (Fig. 6., Px. gang.); the apposed trunks of NN. glosso-pharyngeus (IX), vagus (X), accessorius (XI) and hypoglossus (XII), are embraced by interlacing filaments of N. sympathicus, with which nerve they sustain more or less intimate relations, through anastomotic filaments; N. glosso-pharyngeus is ectal in this group, and, together with its root-ganglion—G. Ehrenritteri, which lies upon the ectal surface of G. jugulare, but which does not seem to sustain anatomical relations with it—may be dissected from the ental trunk; NN. vagus and accessorius are most intimately related—their separation involving the rupture of interlacing fibre—and apparently constitute a single trunk; entad of this united trunk is N. hypoglossus. At the caudal border of this plexus N. accessorius is directed dorsad to be distributed to the muscles of the neck, and N. hypoglossus assumes ectal relations, crossing the ectal surface of N. vagus nearly at right angles, and takes its course ventrad, to the muscles of the tongue. As N. hypoglossus crosses N. vagus, it detaches a filament to G. inferius (Fig. 5, *13*). This region marks the origins of two other rami with whose terminal filaments N. vagus sustains intimate relations, NN. thyro-hyoideus and descendens noni.

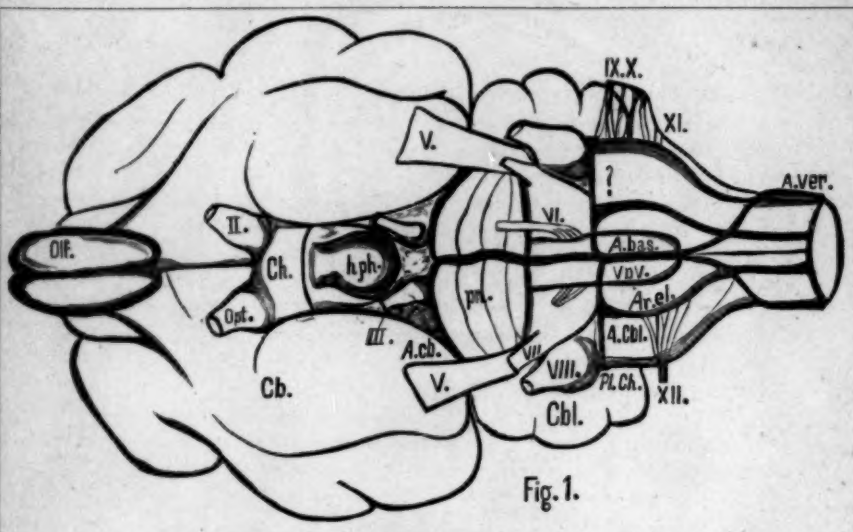


Fig. 1.

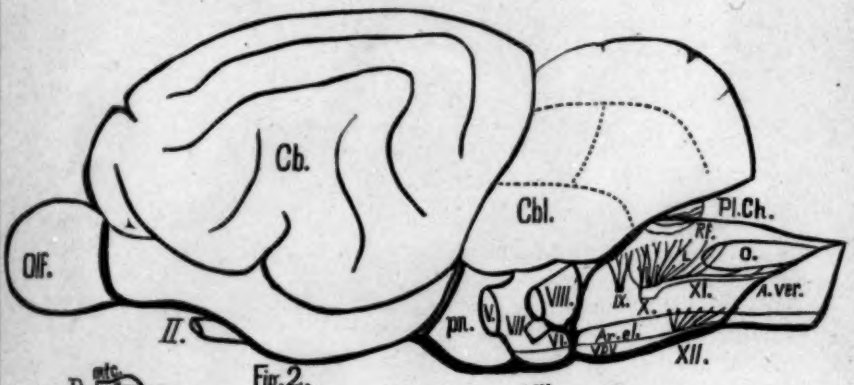


Fig. 2.

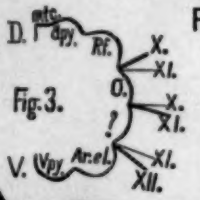


Fig. 3.

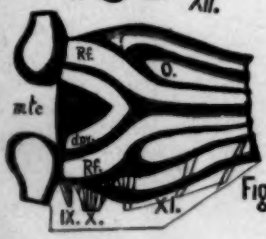


Fig. 4.

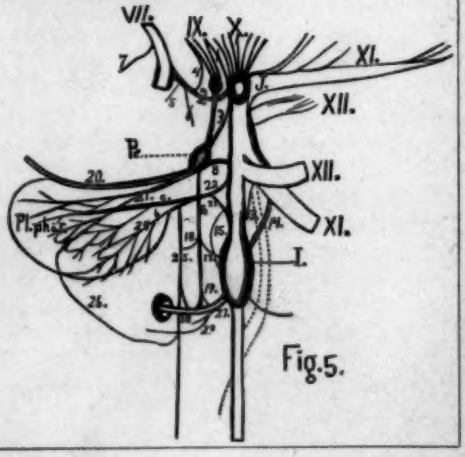


Fig. 5.

15 mm. caudad of G. jugulare and dorsad of the origin of A. carotidea interna, N. vagus receives a second ganglionic enlargement, **ganglion inferius,** ganglion of the trunk (Fig. 5, I.). This ganglion has a fusiform outline 5–8 mm. in caudo-cephalic diameter and 2 mm. in dorso-ventral; it is of a pinkish color; is located ectad of (superficial to) and dorso-caudad of the closely-apposed superior cervical ganglion of N. sympathicus, to which it is very intimately related through anastomotic filaments; its cephalic extremity is apposed to the middle of the superior cervical ganglion. G. inferius does not embrace or involve the main trunk of N. accessorius; it is however joined at its dorso-cephalic border by a large ramus given off from N. accessorius just peripherad of Px. gangliformis (Fig. 5, *14*); it is the superficial origin of a large ramus of N. vagus, viz., N. laryngeus superior; it communicates with N. glosso-pharyngeus (IX) (Fig. 5, *17*), N. accessorius (XI) (Fig. 5, *14*), N. hypoglossus (XII) (Fig. 5, *13*), with the spinal nerves NN. vertebrales, in the loop which connects the first and second cervical nerves, and with N. sympathicus (entad of Px. gangliformis).

In the cervical region N. vagus continues caudad from G. inferius associated with N. sympathicus in the sheath of A. carotidea primitiva. In the cephalic 20 mm. the trunk lies dorso-laterad of A. carotidea externa and A. carotidea primitiva, being concealed within the arterial sheath by the artery and by V. jugularis interna. As the nerve approaches A. occipitalis (?)* it lies laterad of A. carotidea primitiva and crosses the venter of A. occipitalis (?) at its origin; it resumes its dorso-lateral relation 5–8 mm. caudad of A. occipitalis (?) until it enters the thorax. The trunk of N. vagus in its cervical region caudad of G. inferius gives off several ramuli which anastomose with ramuli of N. sympathicus to constitute a more or less dense plexus around the trachea and œsophagus; this is especially marked in the caudal portion of the cervical region. The distinctive courses of the sinistral and the dextral nerves in the thorax require separate descriptions.

The principal rami of the cervical portion of N. vagus are Rm. auricularis, N. pharyngeus, and N. laryngeus superior.

Rm. auricularis, is a large anastomotic branch and has its superficial origin in the dorso-ental border of G. jugulare; its course is curved dorso-laterad and cephalad, and it enters the periotic bone, follows a groove along the dorso-caudal border of the tympanic bulla, traverses the petrous portion of the bone and enters aqueductus Fallopii at a point 2 mm. centrad of the origin of chorda tympani; a portion of Rm. auricularis continues to the opening where it meets the dorsal branch of N. facialis, to be distributed to the ear. A considerable fasciculus crosses N. facialis and may be traced to the cochlea (Fig. 5, *5*). 2 mm. peripherad of its origin Rm. auricularis receives a considerable twig from N. glosso-pharyngeus (IX), and about

* This artery, 25 mm. caudad of foramen of exit and dorsad, or 1-3 mm. dorso-cephalad of A. thyreoidea superior, seems to be allied to A. princeps cervicis. There are some objections to this homology, but the measurements given in the text identify it beyond question.

the same distance, still peripherad, an anastomotic filament from N. sympathicus (Fig. 5, *6*).

N. pharyngeus, the pharyngeal branch, takes its superficial origin from the ventro-ental surface of N. vagus just caudad of the united trunks of NN. vagus and accessorius, 7 mm. caudad of G. jugulare and entad of the point where N. hypoglossus (XII) lies ectad of N. vagus; its origin is, therefore, involved in Px. gangliformis. A considerable accession is traceable through the plexus to the accessory branch of N. accessorius. Its course is ventrad, parallel with N. glosso-pharyngeus (IX), and only 2–3 mm. caudad of that nerve; it lies ectad of A. carotidea interna, and entad of V. jugularis interna and A. carotidea externa; just peripherad of its origin it gives a twig caudad to the trunk, which may be traced to G. inferius (Fig. 5, *23*). Opposite A. carotidea interna it divides into two rami (Fig. 5, *22*, a, b), from which filaments are given to A. carotidea interna and to the adjacent V. jugularis interna. From the *cephalic ramus* anastomotic filaments join N. glosso-pharyngeus (IX) to form a plexus, from which filaments are distributed to the cephalic border of MM. pharyngis constrictor medius, and pharyngis constrictor superior; others anastomose with filaments of N. sympathicus and form the pharyngeal plexus (Fig. 5), other filaments join N. hypoglossus (XII) in this plexus. The *caudal ramus* has its general course caudad; 5 mm. peripherad of its origin, it subdivides into two ramuli, which may be designated, in view of their distribution, as the pharyngeal (Fig. 5–*24*), and the œsophageal (Fig. 5, *25*); the *pharyngeal ramulus* is directed meso-dorsad and forms a loose network with the terminal filaments of the pharyngeal ramuli of N. glosso-pharyngeus (IX)—Px. pharyngeus. The *œsophageal ramulus* gives filaments to MM. pharyngis constrictor medius and pharyngis constrictor inferior. 10–12 mm. caudad of the filaments to the muscles of the pharynx a considerable twig joins the cephalic ramus of N. laryngeus superior and receives an anastomotic filament from the caudal ramus of the same nerve. The œsophageal ramulus continues along the dorsum of the œsophagus caudad as far as the caudal third of the cervical portion, interlacing in the plexus around that viscus.*

N. laryngeus superior, the superior laryngeal branch, is considerably larger than N. pharyngeus; it takes its superficial origin from the ventral border of the middle region of G. inferius; its course is immediately ventrad—occasionally it is directed caudad apposed to the main trunk and ectad of N. sympathicus, 8–10 mm., at which point it turns ventrad—and passes entad of A. carotidea primitiva, where it bifurcates into a cephalic, ental, ramus, *N. laryngeus internus* (Fig. 5, 7, *28*) and a caudal, ectal, ramus, *N. laryngeus externus* (Fig. 7, *29*).

N. laryngeus internus is much larger than N. laryngeus externus; it accompanies A. laryngea superior, and with the artery perforates the hyo-thyroid membrane at the ventro-caudal border of the cephalic cornu

*It sometimes occurs that the caudal ramus is detached caudad of the cephalic ramus of N. pharyngeus; in this case it constitutes a second pharyngeal nerve; this arrangement does not change its distribution.

of Ctl. thyroidea—A. laryngea superior is given off from A. carotidea externa, just caudad of the origin of A. carotidea interna; its course is, therefore, at right angles with A. carotidea externa,

N. laryngeus externus lies ectad of the larynx; it sends a pharyngeal ramulus cephalad and entad of A. laryngea superior (Fig. 7, *30*), which is distributed to M. constrictor pharyngis inferior, anastomoses with the œsophageal ramus of N. pharyngeus (Fig. 7, *31*), gives terminal filaments to Px. pharyngeus and the pharyngeal mucous membrane; filaments of this ramulus anastomose with N. crico-thyroideus and unite in plexiform relation with N. sympathicus around A. thyroidea superior; a twig of this pharyngeal ramulus detached just dorsad of the hyo-thyroid foramen, passes ventro-caudad to terminate in M. crico-thyroideus. This ramus sends a laryngeal ramulus ventro-caudad which lies entad of M. sterno-thyroideus, to which a few filaments are distributed, and is apposed to A. laryngea inferior, which artery it accompanies to the cricoid membrane as far as the ventrimeson (Fig. 7, *32*); from this ramulus filaments are given to M. crico-thyroideus. A caudal ramulus is also detached whose course is dorsad of M. sterno-thyroideus and parallel with its dorsal border to Cp. thyroideum (Fig. 7, *33*); it gives filaments to M. crico-thyroideus and anastomotic filaments to N. descendens noni, which it joins opposite the origin of A. thyroidea superior.

N. laryngeus internus enters the hyo-thyroid foramen and divides into a cephalic and a caudal offset: the *cephalic offset* (Fig. 7, *34*) accompanies the ental portion of A. laryngea superior, pierces M. thyro-arytænoideus to which numerous filaments are distributed, takes its cephalic course obliquely toward the ventrimeson and perforates the thyro-hyoid membrane 2 mm. laterad of the meson. Terminal filaments of this offset supply the epiglottis (Fig. 7, *36*), the arytæno-epiglottidean folds (Id. *37*), the laryngeal glands (Id. *35*), and the mucous membrane of the larynx (Id. *35*, a). A twig given from the cephalic offset, 2 mm. peripherad of the foramen, passes entad of the apposed artery (A. laryngea superior entalis) and joins the caudal offset 2 mm. cephalad of the caudal border of Ctl. thyroidea (Fig. 7 and 8, *39*).

The *caudal offset* lies closely apposed to the ental surface of Ctl. thyroidea (Fig. 7 and 8, *38*); its first twig is sent dorso-caudad and terminates upon M. crico-arytænoideus lateralis, M. arytænoideus and M. constrictor pharyngis inferior (Fig. 8, *40*); anastomotic filaments join in plexiform relation with its dextral homologue and with the pharyngeal and œsophageal plexuses. The principal portion of the caudal offset at its union with the twig from the cephalic offset gives off radiating filaments upon the ectal surface of the arytænoid muscles which constitute a multiple palmate plexus (Fig. 8, *41.*); a twig passes dorsad of the articular facet of Ctl. cricoidea and joins N. laryngeus inferior (Fig. 8. *42*). Near the union of the twig and the offset, entad of cephalic border of Ctl. cricoidea several filaments penetrate M. crico-arytænoideus and are distributed upon the mucous membrane of the larynx.

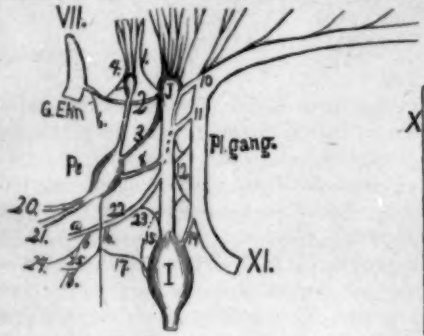


Fig. 6.

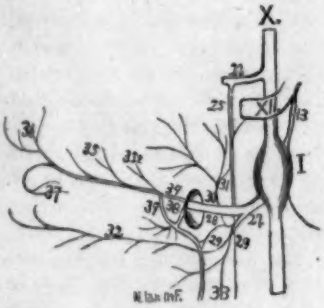


Fig. 7.

Fig. 8.

Fig. 12.

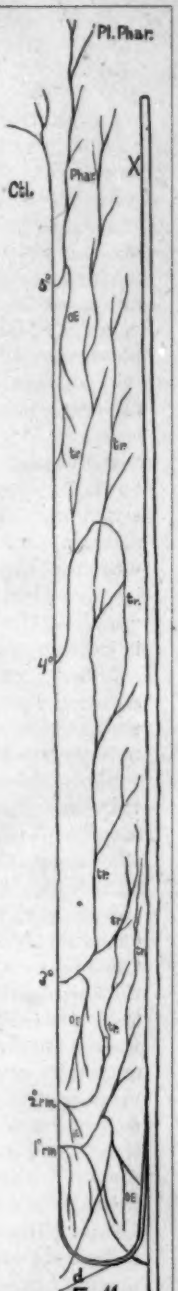


Fig. 11.

Thoracic division of N. vagus sinister: The main trunk of N. vagus sinister enters the thorax dorsad of V. innominata sinistra at the union of V. subclavia and V. jugularis externa, meso-dorsad of V. vertebralis and laterad of A. carotidea primitiva sinistra. In the thorax cephalad of the arch of A. aorta the nerve lies between AA. carotidea and subclavia meso-dorsad of A. sternalis until it reaches a point 10–15 mm. cephalad of A. aorta, at which point it rests upon the ventral surface of A. subclavia and crosses the arch ventro-laterad of the origin of A. subclavia. Opposite the origin of A. sternalis the nerve is crossed by N. phrenicus and lies dorso-laterad of this nerve in the area between the two arteries aforenamed.

As N. vagus enters the thorax, two fasciculi from the middle and caudal areas respectively of the middle cervical ganglion of N. sympathicus, G. thyreoideum, connect N. vagus with N. sympathicus; these commissural fasciculi are about 3 mm. apart. Between a point opposite A. sternalis and the arch of A. aorta the trunk of N. vagus sustains intimate relations with N. sympathicus, N. cardiacus magnus and N. cardiacus minor through numerous anastomotic filaments which constitute a plexiform network around the arteries, trachea and œsophagus in this region of the thorax—AA. subclaviæ, carotideæ primitivæ and innominata. Opposite the caudal border of the arch of A. aorta a considerable fasciculus from the main trunk about 5 mm. in length joins N. laryngeus inferior. 7 mm. peripherad of this fasciculus, where N. largyneus inferior bends around the arch of A. aorta, a ramulus is given off whose interlacings with rami from NN. vagus and sympathicus constitute a plexiform network which is related with the cardiac plexus. In its course caudad of arch of A. aorta, N. vagus passes dorsad of the root of the left lung.

Pulmonary Rami: Between a point opposite the cephalic border of A. pulmonaris and 15 mm. caudad, N. vagus gives several ramuli meso-ventrad to anastomose with terminal filaments of N. cardiacus minor and N. laryngeus inferior in the formotion of the ectal (superficial) cardiac and the ventral (anterior) pulmonary plexuses. From the same region of the main trunk filaments are directed meso-dorsad, which interlace in a dense network with filaments of offsets detached from the main trunk of the area above named, and with terminal filaments of N. cardiacus minor, and other filaments from N. sympathicus to form on the ventral aspect of the trachea just cephalad of its bifurcation, a large plexus, the ental cardiac—*Px. profundus magnus*—from which filaments ramify upon the bronchi and have intimate relations with the plexiform network which is formed by filaments from the offsets named and accessory offsets from thoracic ganglia of N. sympathicus around the bronchi,—dorsal pulmonary plexus. Offsets from this plexus may be traced along the air tubes into the substance of the several lobes and upon the broncho-pulmonary mucous membrane of the sinistral lung. The ramuli which form the dorsal pulmonary plexus are noticeably larger than those given to the ventral plexus.

Œsophageal Rami: Cephalad and caudad of the pulmonary rami

numerous filaments are directed dorsad, by whose anastomoses and union with N. sympathicus is formed the œsophageal plexus which embraces the entire length of the thoracic œsophagus. Caudad of the ramuli given to the pulmonary plexus, 15–20 mm. caudad of the caudal border of the arch of A. aorta, N. vagus sinister divides into sinistral or lateral and dextral or mesal rami (Fig. 9, *46*) which lie respectively upon the sinistral dorsum and venter of the adjacent œsophagus. The *lateral ramus* trends dorso-caudad, and 50–60 mm. peripherad of its origin it unites with the lateral ramus of N. vagus dexter in a median line upon the dorsum of the œsophagus, to constitute a single dorsal trunk for about 25 mm. (Fig. 9, *47*). Numerous anastomotic filaments from the two rami of N. vagus sinister and the rami of N. vagus dexter interlace in the œsophageal plexus from which filaments are given to the muscular tissue and mucous membrane of the œsophagus. The united dorsal trunk perforates the diaphragm and enters the abdomen as the *gastric nerve*.

The *mesal ramus* of N. vagus sinister trends ventro-caudad, and 20–25 mm. peripherad of its origin is joined by its dextral homologue (Fig. 9, *48*), and these two mesal rami constitute a united ventral trunk which lies in the caudal mediastinum upon the venter of the œsophagus and perforating the diaphragm near the meson, lies on the venter of the cardia (Fig. *13*). A slight twig connects the two mesal rami 2 mm. peripherad of their origins. From the thoracic portion of the ventral trunk anastomotic filaments are given to its homologue in the formation of the œsophageal plexus.

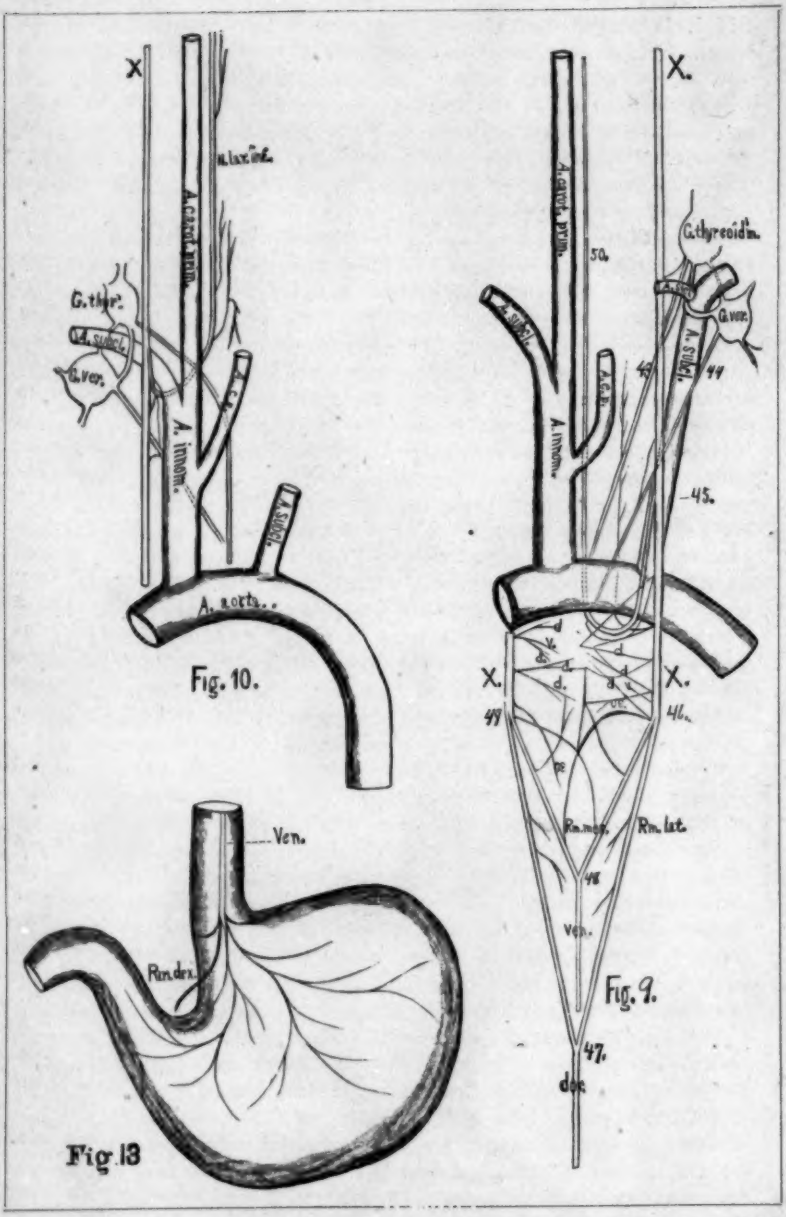
The thoracic portion of N. vagus dexter lies ventrad of A. subclavia and mesad of A. sternalis; at the caudal border of A. subclavia it bends slightly dorsad to pass mesad of V. vertebralis at its junction with V. innominata, it continues laterad of the trachea, entad of V. azygos and dorsad of the root of the right lung. As the main trunk enters the thorax it sustains intimate relations through anastomotic twigs with N. cardiacus magnus, N. cardiacus minor and the inferior cervical ganglion of N. sympathicus (Fig. 10). 15 mm. caudad of A. subclavia a considerable ramus is directed meso-caudad and accompanies a large ramus detached entad of V. azygos; these cardiac rami pass meso-ventrad around the base of the right pulmonary artery and to the right auricle (Px. cardiacus ectalis). Three or four ramuli are given off between A. subclavia and V. azygos whose ramifications interlace the plexus of the trachea and œsophagus. From the 12–14 mm. of the trunk dorsad of the lung, numerous filaments are directed mesad and ventrad to join the pulmonary plexus (Fig. 9). Caudad of this point and opposite the bifurcation of its sinistral homologue the dextral nerve bifurcates into lateral and mesal rami (Fig. 9, *49*); caudad of the bifurcation the lateral ramus trends dorso-caudad until it joins its sinistral homologue already described. The mesal ramus gives recurrent ramuli cephalad to the dextral border of the pulmonary plexus. Several other anastomotic filaments are detached from the ramus between the root of the lung and the union with its fellow which terminate in the œsophageal plexus (Fig. 9).

NN. laryngei inferiores, recurrent or inferior branches of N. vagus, tracheal recurrents, have the following *general characters in common*, viz.: their general cephalic direction; their disposition along the dorso-lateral border of the trachea; the anastomotic character of their ramuli; the distribution of the terminal filaments; the sensory function of the fibre. *Distinctive characters:* their origin; their length; their disposition in the thorax; the relative number of anastomotic filaments; the number of tracheo-œsophageal ramuli.

Special description: *N. laryngeus inferior sinister*, the sinistral recurrent nerve, branches from the mesal aspect of the main trunk of N. vagus, 1–3 mm. cephalad of the arch of A. aorta (Fig. 9, 45);* its course is caudad, apposed to the mesal side of the main trunk as far as the root of A. subclavia sinistra where the main trunk crosses the arch of A. aorta. Upon the ventral aspect of the arch of A. aorta, N. laryngeus inferior separates from the main trunk upon the mesal side, and twisting around the concave aspect of the arch about 1 mm. sinistrad of the obliterated "ductus arteriosus," it trends meso-dorsad, and returns cephalad along the dorso-lateral border of the trachea, between the trachea and the œsophagus, as a "recurrent nerve" (Fig. 9, *50*). At the caudal border of the larynx N. laryngeus detaches several ectal filaments to M. crico-thyroideus (Fig. 8), passes entad of a caudal twig of A. thyroidea superior, bends dorsad around the articular facet of Ctl. cricoidea (Fig. 8) and enters the larynx as an ental nerve. A slender anastomotic twig passes ectad of the arterial twig named and may be traced dorsad of the nerve trunk until it joins a corresponding twig from the caudal division of N. laryngeus superior (Fig. 7, *29*, a). Pharyngeal ramuli from the ental nerve are distributed to M. constrictor pharyngis inferior; other dorsal filaments supply M. arytænoideus posterior and M. arytænoideus; ventral filaments supply MM. crico-arytænoideus lateralis and thyro-arytænoideus, while terminal filaments reach the sub-glottic mucous membrane. Upon the ectal surfaces of MM. crico-arytænoideus posterior and crico-arytænoideus lateralis a multiple palmate plexus is formed by anastomotic filaments of NN. laryngeus superior and laryngeus inferior (Fig. 8, *41*).

N. laryngeus inferior dexter is detached from the main trunk of N. vagus, 12 mm. cephalad of the origin of A. subclavia, where the main trunk is disposed upon the ventral aspect of A. subclavia (Fig. 10); N. laryngeus dexter is immediately directed caudad over the venter of the artery, is reflected around the caudal aspect, and assumes a meso-dorsal direction to the dextral side of the trachea, and is disposed like its sinistral homologue, with the exception of having fewer anastomotic filaments. Peripherad of the origin of N. laryngeus inferior dexter, dorsad of A. subclavia, ramuli are given to the deep cardiac and the posterior pulmonary plexuses; another ramulus cephalad joins its sinistral fellow, a third, the thoracic cardiac, is directed caudad by the side of the main trunk of N. vagus dexter, and terminates in the dextral bronchial plexus. As N.

* An occasional origin is 8–10 mm. cephalad of cephalic border of arch of A. aorta.


X
a. lax. inf.
A. carot. prim.
G. ther.
A. thyr.
G. ver.
A. innom.
A. subcl.
A. aorta.
Fig. 10.
X.
A. carot. prim.
50.
G. thyreoidm.
A. thyr.
G. ver.
A. subcl.
49
44
A. innom.
45.
X.
X.
49
46.
Rm. mast.
Rm. lat.
48
ven.
Fig. 9.
47.
duc.
Ven.
Ram. dex.
Fig. 13

laryngeus inferior dexter bends around A. subclavia, just dorsad of A. sternalis, a branch is given off caudad, which, 10–12 mm. from its origin, joins N. cardiacus minor (Fig. 10), and these apposed trunks are joined 5 mm. peripherad by N. cardiacus magnus dexter, and the trunk thus constituted passes dorsad of V. cava descendens and A. innominata to the dorso-caudal border of the arch of A. aorta, where it terminates in Px. magnus profundus, from which filaments proceed to the ventral and dorsal coronary and the pulmonary plexuses.

Tracheo-œsophageal ramuli of N. laryngeus inferior (Fig. 11, 12). *General characters:* these ramuli of the sinistral and dextral nerves have in common the following characters—their origin; general direction; numerous terminal filaments; the plexiform relation of these filaments; their mode of entering larynx; their distribution upon its mucous membrane; distribution of the dorsal filaments to œsophagus. *Distinctive characters:* the smaller number of ramuli from the dextral side than from the sinistral; the homologue of the first sinistral nerve is always found as a ramulus from the main trunk caudad of the origin of N. laryngeus inferior dexter (Fig. 12); the terminal filaments of the dextral side are less numerous than those of the corresponding nerves of the sinistral side.* *Special description:* opposite the cephalic border of the arch of A. aorta the first tracheal ramulus is detached (Fig. 11, 1°rm.); a considerable offset is directed caudad from the origin to Px. magnus profundus; 2 mm. peripherad of origin an anastomotic filament joins N. vagus 8 mm. caudad of origin of N. laryngeus inferior; 6 mm. peripherad of origin the ramulus bifurcates, the longer division is distributed upon the dorsum of the trachea 30 mm. cephalad of the arch of A. aorta; the shorter or caudal division sends filaments to Px. cardiacus ventralis, to Px. magnus profundus and to the bronchioli.

Five mm. cephalad of the first ramulus a second is given to the venter and the sides of the trachea over that portion corresponding to the distribution of the cephalic division of the first ramus upon the dorsum.

Ten mm. cephalad of the second ramulus and nearly opposite the origin of A. sternalis, the longest ramulus is detached; this divides into three offsets, the caudal is distributed to the venter of the œsophagus, the median to the sides of the trachea, the cephalic lies just laterad of the ventrimeson and gives two considerable fasciculi, whose terminal filaments supply the walls of the trachea; the terminal filaments of the ramulus are traceable nearly to Ctl. cricoidea.

Opposite the sixth cervical vertebra the fourth ramulus is detached, whose filaments anastomose with the preceding ramulus, and supply the dorsum of the trachea and venter of adjacent œsophagus along the entire cervical region from the thorax to the larynx.

The fifth tracheal ramulus takes its origin 10mm. caudad of Ctl. cricoidea

* The double ramuli sometimes occur with separate origins; this apparent increase of ramuli may be regarded as a modification and not a violation of the plan. In the special description the details of measurements of a single specimen are given.

(Fig. 8 and 11, 5°). This ramulus is largely if not exclusively œsophageal and joins in Px. pharyngeus; the caudal or recurrent portion is reflected caudad upon the œsophagus.

Gastric nerves: Caudad of the diaphragm the **dorsal gastric nerve** splits into several terminal ramuli, the longest of which terminates in ganglion semi-lunare of the great solar plexus, *Px. solaris;* near the cardia numerous filaments are distributed to the cardia; offsets supply the lesser curvature of the stomach, the plexus around A. coronaria ventriculi, and the dorsal surface of the stomach; ramuli may be traced to the plexus around A. hepatica (Px. hepaticus), A. splenica (Px. splenicus), A. mesenterica superior (Px. mesaræicus). At the cardia, terminal filaments of the **ventral trunk** are distributed to the lesser curvature of the stomach, a few join terminal filaments of the dorsal trunk (Fig. 13), and others still may be traced to the great solar plexus, from which ramuli enter the gastro-hepatic omentum and join the hepatic plexus. This anastomosis of the dorsal and ventral trunks in the solar plexus constitutes the "memorable loop of Wrisberg."

SUMMARY.

A. Anatomical. 1. Origin—12–14 filaments along a line ventro-laterad of Cp. restiforme, and by 4–6 filaments ventrad of oliva.

2. **Foramen of exit**—foramen lacerum posterius.

3. **Ganglia**—G. jugulare, in the proximal end of foramen of exit—G. inferius, 15mm. peripherad.

4. **Relations of ganglia**—G. jugulare, with NN. facialis (VII), glosso-pharyngeus (IX), accessorius (XI), sympathicus; G. inferius, with NN. glosso-pharyngeus (IX), accessorius (XI), hypoglossus (XII), pharyngeus, laryngeus superior, sympathicus.

5. **Px. gangliformis**—the 5 mm. of trunk peripherad of G. jugulare; it is formed by accessory portion of N. accessorius, anastomotic filaments between NN. vagus and accessorius, filaments to N. pharyngeus, and N. sympathicus.

6. **Principal rami**—respective origins and general distribution: Rm. auricularis, G. jugulare to N. facialis; N. pharyngeus, Px. gangliformis to Px. pharyngeus and œsophagæus; N. laryngeus superior, G. inferius to larynx; N. laryngeus inferior, N. vagus near arch of A. aorta to trachea and œsophagus; Rm. cardiaci, trunk of N. vagus proximad of base of heart to Px. cardiaci; Rm. pulmonares, trunk of N. vagus proximad of root of lungs to Px. pulmonares; anastomotic filaments to N. sympathicus.

7. **Bifurcation**—dorso-laterad from roots of lungs into lateral and mesal rami.

8. **Formation of nerve trunks**—dorsal trunk by union of lateral rami = dorsal gastric nerve (N. gastricus dorsalis)—ventral trunk by union of mesal rami = ventral gastric nerve (N. gastricus ventralis).

9. **Termination**—ganglia semi-lunaria of Px. solaris in loop of Wrisberg.

B. Physiological—sensibility of mucous membrane of pharynx, larynx, trachea, bronchi, bronchioli—motion of pharynx, larynx; reflex movements of broncho-pulmonary passages, œsophagus and stomach—action upon secretions, e. g., gastric juice, biliary products, etc.*—indirect influence upon phenomena of respiration and of "inhibition."

EXPLANATION OF THE NUMBERS AND ABBREVIATIONS USED IN THE FIGURES.

A. bas., A. basilaris; A. cb., A. cerebralis posterior; A. cbl., A. cerebellosa inferior; A. ver., Arteria vertebralis; Ar. el., area elliptica (possibly related to olivary body); ?, elongated, pyriform area lateral from Ar. el., whose homology is not determined; Cb., cerebrum; Cbl., cerebellum; Ch., chiasma; dpy., dorsipyramis (posterior pyramid); Ehr., G. Ehrenritteri; hph., hypophysis; I., G. inferius; J., G. jugulare; mtc., metacœlia (fourth ventricle); O., oliva, corpus olivarium (?); olf., lobus olfactorius; opt., N. opticus; Pe., G. petrosum; Px. ch., plexus choroideus lateralis; Px. phar., plexus pharyngeus; Pn., Pons Varolii; Rf., corpus restiforme; Vpy., ventripyramis (anterior pyramid); II., N. opticus; III., N. motor oculi; V., NN. trigemini; VI., N. abducens; VII., N. facialis; VIII., N. auditorius, Portio mollis; IX., N. glosso-pharyngeus; X., N. vagus; XI., N. accessorius; XII., N. hypoglossus; 1, accessory filament from N. glosso-pharyngeus; 2, Rm. auricularis; 3, anastomotic twig from J. to Pe.; 4, filament from origin line of IX. to 2; 5, ramulus from 2 to cochlea; 6, anastomotic twig to N. sympathicus; 7, chorda tympani; 8, anastomotic twig from Pe. to X.; 10, Rm. accessorius from XI.; 11, second accession from XI.; 12, anastomotic filaments between X. and XI.; 13, filament from XII. to I.; 14, Rm. from XI. to I.; 15, superior cervical ganglion of N. sympathicus; 16, pharyngeal ramus from IX. at Pe.; 17, anastomotic filament from 16 to I.; 18, anastomotic filament from 16 to Px. phar.; 19, filament from 16 to N. laryngeus superior; 20, cephalic ramus of IX.; 21, caudal ramus of IX.; 22, N. pharyngeus; 22 a, cephalic ramus; 22 b, caudal ramus; 23, filament from 22 to I.; 24, pharyngeal ramus of 22 b; 25, œsophageal ramus of 22 b; 26, filament from 25 to 22 a; 27, N. laryngeus superior; 28, cephalic = ental ramus; 29, caudal = ectal ramus; a, twig to 50; 30, pharyngeal ramus of 29; 31, filament from 30 to 25; 32, Rm. of 29 to Mb. crico-thyroidea; 33, to Cp. thyroideum, a, to descendens noni; 34, cephalic offset of 28; 35, filaments to interior of larynx; 36, to epiglottis; 37, to aryt eno-epiglottidean folds; 38, caudal offset of 28; 39, twig from 34 to 38; 40, twig from 38 to M. arytænoideus, etc.; 41, palmate plexus; 42, ramus to 50; 43, N. cardiacus magnus sinister; 44, N. cardiacus minor; 45, origin of 50; 46, division of N. vagus sinister; 47, union of lateral rami; 48, union of mesal rami; 49, division of N. vagus dexter; 50, N. laryngeus inferior.

*The extent to which se retions and excretions may be referred directly to N. vagus is questionable.

Description of the figures.

Fig. 1.—General view of venter of brain ; special reference to venter of medulla, area post pontilis, showing relations of lines of origin-filaments of NN. glosso-pharyngeus, vagus, and hypoglossus ; also ectal relations, ventripyramis (vpy.), area elliptica (ar. el.), and the lateral tract (?).

Fig. 2.—View of sinistral surface of brain, special reference to curved line of origin-filaments of N. vagus and to origin line (L) ventrad, and their relations ; the cephalic filaments of N. accessorius (XI) are in the depression line ventral from Rf., while the caudal filaments have their origin in the depression line lateral from O.

Fig. 3.—Diagram to show the origin of N. vagus ventro-lateral to Rf. ; also that N. accessorius (XI) has its cephalic filaments from the same depression line, and its caudal filaments from the depression line ventro-lateral to O ; N. hypoglossus (XII) is dorso-lateral to ar. el.

Fig. 4.—Dorsal aspect of metencephalon (medulla) showing origins of NN. IX, X, XI ; metacœlia (mtc.), dorsipyramis (dpy.), corpus restiforme (Rf.), oliva (O), and the lateral tract (?).

Fig. 5.—To show relations of origin-filaments ; of Rm. auricularis ; of G. jugulare ; of G. petrosum ; of G. inferius. G. Ehrenritteri is removed from its normal relation which is ectal to G. jugulare, and is placed cephalad to expose the parts. N. XII, is reflected dorsad to expose origin of N. pharyngeus and anastomotic ramus from Pe. The dotted lines represent NN. hyo-thyroideus and descendens noni. Px. phar. = pharyngeal plexus.

Fig. 6. is Fig. 5, dissected to show Rm. accessorius given to J., and the second accession to the trunk peripheral to J. ; N. XII, is omitted as are the anastomotic filaments of Px. gangliformis ; the dotted line shows the direction of the filaments from N. XI, to N. pharyngeus.

Fig. 7.—N. laryngeus superior ; origin ; division ; distribution of ental or cephalic and ectal or caudal rami ; anastomotic relation between pharyngeal ramulus of the ectal ramus and the œsophageal ramus of N. pharyngeus.

Fig. 8.—N. laryngeus inferior. To show the laryngeal relations of N. laryngeus inferior ; entad of Ctl. thyroideus ; the palmate plexus ; the anastomotic filaments of NN. laryngeus superior and laryngeus inferior ; the pharyngeal ramus of N. laryngeus inferior (5°).

Fig. 9.—N. laryngeus inferior sinister. To show its origin ; relations with A. aorta and adjacent plexus ; relations of N. vagus with N. sympathicus ; division of N. vagus dorso-caudad of root of lungs ; the relations of the lateral and the mesal rami ; the dorsal and the ventral pulmonary plexus ; the formation and the relations of the dorsal and the ventral nerve trunks.

Fig. 10.—N. laryngeus inferior dexter. To show its origin ; its relations with A. subclavia ; relations of N. vagus with N. sympathicus.

Fig. 11 and 12.—Tracheo-œsophageal ramuli of N. laryngeus inferior sinister and dexter respectively.

Fig 13.—Distribution and relations of the ventral gastric nerve and the ramus which terminates in the dextral G. semilunare of Px. solaris.

Contributions to the History of the Vertebrata of the Lower Eocene of Wyoming and New Mexico, made during 1881. By E. D. Cope.

(*Read before the American Philosophical Society, Dec. 16, 1881.*)

I. The Fauna of the Wasatch Beds of the Basin of the Big Horn River.

The basin of the Big Horn river contains the most northern area of the deposits of the Wasatch or Suessonian epoch known. In order to ascertain whether the fauna it contains differs in any way from that I discovered in the corresponding beds of New Mexico in 1874, I sent, during the past season, an expedition, under the direction of J. L. Wortman, already known from his successful exploration of the Wind River basin in 1880. The present paper gives a review of the results of the season's work, prefaced by an account of the geology furnished by Mr. Wortman. The species herein described are being engraved for the fourth volume of Dr. Hayden's report of the United States Geological Survey of the Territories, now passing through the press.

1. *The Geology of the Big-Horn Basin, by Jacob L. Wortman.*

As early as 1859 Dr. Hayden described in detail the Tertiary sediment occupying the upper drainage basin of the Big-Horn river, which he determined as belonging to the lower Eocene formation, and applied the name Wind River group, from its being exposed along the Wind river, a name given to the upper portion of the Big-Horn. From an extensive collection of vertebrate fossils made by the writer at this horizon, during the summer of last year, Prof. E. D. Cope, for whom the collection was made, has, in a bulletin, U. S. Geol. Surv. Terrs., F. V. Hayden, Vol. vi, No. 1, 1881, confirmed this determination, and discussed at length the faunal relations they bear both to the Bridger and Wasatch beds respectively. The conclusions reached are, that this series is intermediate to a certain degree, containing genera hitherto regarded as peculiar to each. This upper basin covers quite an extensive area, and is bounded upon every side by lofty mountains. The Owl Creek mountains, which afforded a barrier to the waters of this Eocene lake on the north, has subsequently been cleft by the Big-Horn, leaving a deep and rough cañon, through which it now flows in its course north to the Yellowstone. After passing the Owl Creek mountains it emerges into a second or lower basin, commonly called the Big-Horn basin proper. This one covers a much larger area than the upper, and like it is walled in by mountain ranges, and filled with a mass of sedimentary rock which is also referable to the lower Eocene series.

During the summer of the present year the writer has been engaged in further exploration of this interesting region, which resulted in the collection of a large number of extinct vertebrates, obtained exclusively from the lower Eocene horizon of the Big-Horn, and which have all been sub-

mitted to Prof. Cope, at whose instance the party was organized and equipped.

Dr. Hayden has made the observation that upon the eastern slope of the Wind River mountains all the corresponding strata are visible from the Silurian to the Cretaceous; this is also true of the northern slope of the Owl Creek mountains, while the southern side does not exhibit such continuity of structure. Upon entering the basin from the south, the older formations are seen to extend towards its centre for a distance of ten miles, inclining at an angle of 30° to the north, while the level of the Tertiary has been little or not at all disturbed since its deposition. That this basin contained a separate and isolated body of water, limited by its present boundaries, which were outlined about the beginning of the Wasatch epoch, there is every reason to believe. A section made by the Big-Horn at the southern extremity shows the Tertiary to rest unconformably upon a thick mass of buff colored sandstone, rather coarse in texture, somewhat laminated, and towards the bottom interspersed with thin layers of impure lignite varying from six inches to one foot in thickness. This sandstone most probably belongs to the Laramie series, but in the absence of fossils the determination is by no means satisfactory.

The Eocene sediment covers a large part of the basin, and cannot be less than 4000 feet in vertical depth. This mass, once continuous over a large area, has since been carved and weathered into many fantastic and remarkable forms, presenting at once a bold and striking appearance, a characteristic feature of the western Tertiary bad lands.

Beginning at the southern limit at a point opposite the mouth of Meyers creek, on the east side of the river, a series of low bad land bluffs, facing to the west and gradually becoming higher as they proceed, describe a gentle curve to the north, terminating at the river's edge 30 miles below. The character of the country between the river and these bluffs is a barren sage brush plain, while back of the bluffs a high mesa occupies the country for many miles. On the west side, numerous rivers, creeks, and their tributaries, putting down from the Sierra Shoshone range, have excavated the mass in every direction, leaving bold escarpments, high bad land buttes, elevated tables, with innumerable gulches and ravines. Country of this character stretches far away to the northern limit, near the Big Horn gap, presenting that desolate and sombre appearance, so often met with in bad land regions.

Its composition may be described as consisting of various colored clays alternating with layers of brown and blue sandstone, although that evenness of stratification by which a single layer of either, in one part, could be identified in another, does not exist. Those exposures, for example, on the east side of the Big-Horn are highly arenaceous, the clay and sand existing in almost equal proportions, while in the exposures along the Grey Bull river, and in the vicinity of Coryphodon butte, the quantity of sand is greatly diminished, and is found in separate layers. The preponderance of the red clay is a marked feature, and has called forth the

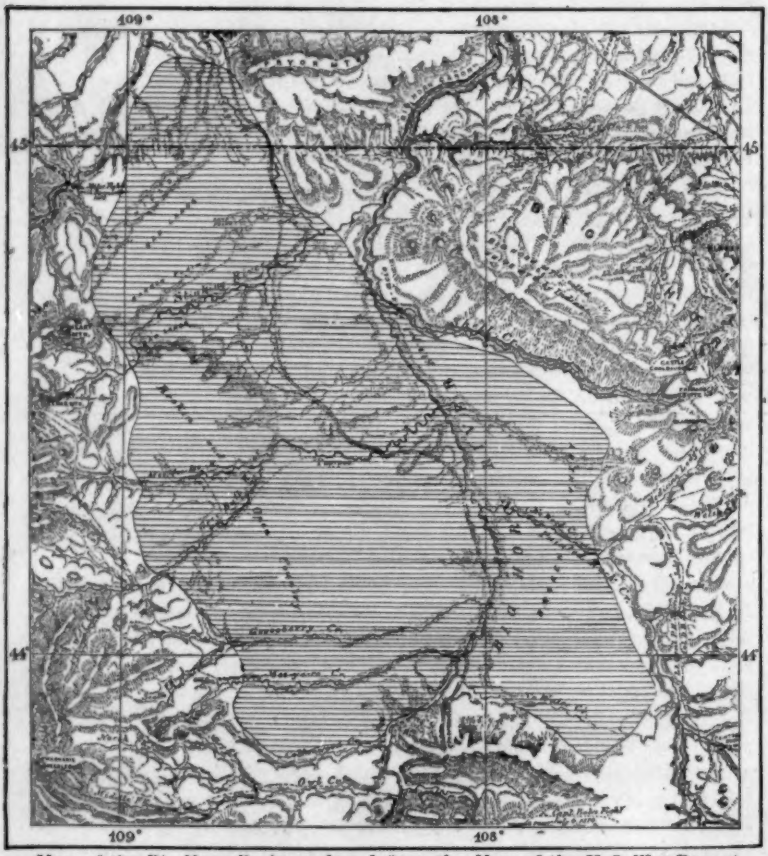
remark from Dr. Hayden, relative to the sediment of the upper basin, "that they remind one of the Jura Trias red beds." This remark is forcibly illustrated by the character of the sediment found in the south-western part of the basin, near the head of Gooseberry creek, where the exposures consist largely of thick strata of the red clay, which gradually thin out to the north and east, blending with the pink, blue, and buff colors. In the northern part of the basin, and along Stinking river, the sediment consists almost exclusively of a pale yellow sandstone of a bluish tinge, from which few fossils were obtained.

The clays contain much lime in the form of small limestone nodules of a rusty brown appearance, in which the fossils are often found, having a thin and intensely hard layer of ferrous oxide investing them externally. In the red the fossils are always scarce and fragmentary, and when found are usually such parts as would, under the most favorable circumstances, be preserved. The blue seems to be the more productive, and to have offered better conditions for their preservation; but, owing to the fact that lime forms the petrifying base, and being less able to withstand the heavy pressure than many other materials, the fossils from both the red and the blue are, as a general rule, greatly distorted and crushed. This fragmentary occurrence of fossils in the fine-grained clay, I am inclined to believe, is due, not to a scattering of the bones by currents, but rather to imperfect and unfavorable conditions for their preservation. That entire skulls and skeletons were deposited, where now nothing but the teeth remain, I am well satisfied from the circumstance that both superior and inferior series are not unfrequently found in proper position without a trace of ramus or cranium. In the sandstones, however, the fossils are in a magnificent state of preservation, but their extreme scarcity in this material gives the collector many long and fruitless searches. Two skeletons which have proven of considerable interest were all of any consequence that were obtained from the sandstones.

The general stratigraphical appearance, as well as the scattered and fragmentary condition of the fossils, together with the community of a large number of genera, refer it to the Wasatch epoch, but a full discussion of this point belongs properly to the paleontologist. A thorough elucidation will be found in Prof. Cope's paper on the fossils.

The exploration of this region is most arduous and difficult. The great scarcity of water in these bad land wastes, makes it very inconvenient, and renders it necessary to carry a water supply a distance of often 20 miles or more. Even when water does exist it is so strong with alkali as to be scarcely fit for use. Many of the streams coming down from the mountains dry up as soon as the snow has melted from the low foot hills in early spring, leaving large tracts entirely destitute of water, which frequently abound in fossiliferous exposures, and which it is the object of the explorer to examine. The broken and mountainous character of the country forbids the use of wagons to such an extent that pack animals are indispensable.

The accompanying map is intended to illustrate the exact position, as well as the extent of country covered by the Wasatch sediment at this point. Its topography is taken from a map made by Capt. J. Russell, Third Cavalry, U. S. A. (and published by the War Department), during a reconnoissance of that region in the summer of 1880, and to whom, as well as Dr. W. H. Corbusier, Col. J. W. Mason, and other officers stationed at Fort Washakie, I wish to express my deep sense of obligation for their very kind and courteous treatment.



Map of the Big-Horn Basin, reduced from the Map of the U. S. War Department.

2. *Synopsis of the Fauna.*

PISCES.

CLASTES sp. ; not abundant.

PAPPICHTHYS sp. Vertebræ ; not very common.

REPTILIA.

CROCODILUS sp. Allied to the *C. chamensis* and *C. heterodon*, but not represented by sufficiently well preserved specimens to permit of determination. There are numerous molariform teeth in the posterior parts of jaws, and the crowns of the longer teeth are grooved. Not uncommon.

EMYS sp. Rare; one specimen of 220 mm. in length, of the type of *E. wyomingensis*, but not sufficiently well preserved for determination.

As the Eocene forms of this order are of unusual interest, I give an analysis of the extinct genera of the Cryptodire division of tortoises which have been found in North America up to the present time.

In the check-list of the North American *Batrachia* and *Reptilia*,* I enumerated nine families of this division of the *Testudinata*, three of which are extinct. Subsequently another extinct family, the Baënidæ, was added. I now define all of these families.

I. Plastron not articulated to the carapace, but presenting to it more or less open digitations. *Dactylosterna.*

Phalanges of anterior limb without condyles, and covered by a common integument; eight pairs of costal bones.....*Chelonïidæ.*

Phalanges of anterior limb without condyles; nine or more costal bones, *Propleuridæ.*

Phalanges of anterior limb with condyles; digits inclosed in distinct integuments; eight costal bones; sternal elements united by digitations and inclosing fontanelles; caudal vertebræ procoelous...*Trionychidæ.*

Phalanges of anterior limbs with condyles; digits distinct; eight costal bones; sternal elements united by suture and inclosing no fontanelles; caudal vertebræ opisthocoelous.....*Chelydridæ.*

II. Plastron uniting with the costal bones of the carapace, by denticulate suture, and by ascending axillary and inguinal buttresses. (Feet ambulatory.) *Clidosterna.*

A. Intersternal bones present.

No intergular scuta.....*Pleurosternidæ.*†

Intergular scuta; caudal vertebræ opisthocoelous.....*Baënidæ.*

AA. No intersternal bones.

a. Intergular scuta.

A mesosternal bone.....*Adocidæ.*

aa. No intergular scuta.

A mesosternal bone; three series of phalanges.....*Emydidæ.*

No mesosternal bone; three series of phalanges.....*Cinosternidæ.*

A mesosternal bone; two series of phalanges.....*Testudinidæ.*

* Bulletin U. S. National Museum, No. 1, 1875, p. 16.

† There are two genera of this family, neither of them yet found in America; *Pleurosternum* Ow., with smooth shell, and *Helochelys* Myer, with sculptured shell.

III. Plastron uniting with the marginal bones of the carapace by straight contact only. (Feet ambulatory.) *Lysosterna.*

No intersternal bone nor intergular scutum; a mesosternal bone and three series of phalanges..... *Cistudinidæ.*

The extinct species of the *Cryptodira* of this continent belong to eight of the above families. I give diagnoses of the genera to which they are referred. Names of existing genera are in Roman type.

CHELONIIDÆ.

Postabdominal bones distinct from each other.....Chelonia Brong.
Postabdominal bones united with each other by suture..*Puppigerus* Cope.

PROPLEURIDÆ Cope.*

Transactions of American Philosophical Society, xiv., 1870, p. 235.

Ten costal bones; first two marginals united with carapace by suture; shell smooth, flattened..... *Osteopygis* Cope.
Nine costal bones; first two marginals united to carapace by suture; shell sculptured (a high dorsal keel)..... .....*Peritresius* Cope.
Nine costal bones; one marginal united with carapace by suture; second by costal gomphosis; shell not keeled nor sculptured ..... *Propleura* Cope.
? Nine costal bones; first united with carapace by suture; second without costal gomphosis; shell not sculptured.....*Catapleura* Cope.
? Nine costal bones; marginals all free; shell not sculptured ..... *Lytoloma* Cope.

TRIONYCHIDÆ.

a. Surface of bones smooth.

Postabdominal suture digitate .....*Axestus* Cope.

aa. Surface of bones sculptured.

β. Sutures of plastron digitate.

A dermal flap protecting posterior legs below; marginal bones..... Emyda Gray.
A dermal flap; no marginal bones.....Cyclanosteus Peters.
No dermal flap nor marginal bones; muzzle much abbreviated..... Chitra Gray.
No dermal flap nor marginal bones; muzzle elongate....Trionyx Geoffr.

ββ. Suture for postabdominal coarsely serrate.

Postabdominal recurved in front.....*Plastomenus* Cope.

CHELYDRIDÆ.

a. Bridges of plastron wide; ? caudal vertebræ.

One row of marginal scuta; six pairs of scuta of the plastron..... *Idiochelys* Myr.

* *Palæochelys novemcostatus* Geoffr., belongs to this family, but not *Palæochelys* Myr.

One row of marginal scuta ; scuta of plastron ? not distinct.....
Hydropelta * Myr.

aa. Bridges of plastron very narrow.

β. Carapace smooth, not sculptured.

Two rows of marginal scuta ; five pairs of scuta of the plastron.....
Macrochelys Gray.

One row of marginals ; five pairs on plastron.....Chelydra Schw.

One row of marginals ; four pairs of scuta on plastron....Claudius Cope.

ββ. Carapace sculptured.

One row of marginal scuta.....*Anostira* Leidy.

BAËNIDÆ.

Cope, Annual Report U. S. Geol. Surv. Terrs., 1872 (1873), p. 621.

Supramarginal scuta (Rütimeyer) ; no interhumerals.....*Platychelys* Myr.

No supramarginals nor interhumeral scuta.....*Baëna* Leidy.

No supramarginals ; interhumeral scuta present .....*Polythorax* † Cope.

ADOCIDÆ.

Cope, Proceedings American Philosophical Society, 1870, p. 559.

a. Vertebral bones and scuta normal.

One intergular scutum entirely separating the gulars .....*Adocus* Cope.

Either two intergulars, or the gulars meeting behind intergular.....
Amphiemys Cope.

aa. Vertebral bones wedge-shaped, widening upwards ; vertebral scuta not wider than the bones.

Elements of carpace early coössified.....*Homorhophus* Cope.

EMYDIDÆ.

a. No scutal sutures.

Surface sculptured.....*Apholidemys* Pom.

aa. Scuta including intermarginals and two anals.

Lobes of sternum narrow.....Dermatemys Gray.

Lobes of sternum wide.....*Agomphus* Cope.

aaa. Scuta ; two anals, no intermarginals.

Surfaces of carapace sculptured ; plastron fixed.....*Compsemys* Leidy.

Surfaces of carapace smooth ; plastron fixed ; recent *Emydidæ* and the genus.....Emys Brong.‡

Posterior lobe of plastron movable ; surface smooth....*Ptychogaster* Pom.

Anterior and posterior lobes of plastron movable ; surface smooth.....
Dithyrosternum Pict. et Humb.

aaaa. Scuta ; one anal, no intermarginals.

Carapace smooth .....*Stylemys* Leidy.

* *Eurysternum* Wagn. (*Palæomedusa* et *Acichelys* Myr. (fide Rütimeyer) is nearly allied to *Hydropelta*.)

†Possibly one of the *Adocidæ* ; see Proceed. Acad. Phila., Oct., 1876.

‡ Gray has distinguished several good genera among existing species on cranial characters.

TESTUDINIDÆ.

a. Two anal scuta.

Ten abdominal scuta..... .....*Hadrianus* Cope.

aa. One anal scutum.

Lower jaw with two cutting edges.....Xerobates Agass.
Lower jaw with one cutting edge.....Testudo Linn.

RODENTIA.

PLESIARCTOMYS BUCCATUS Cope.

Two mandibular rami.

PLESIARCTOMYS DELICATIOR Leidy.

Mandibles of six individuals, some of them accompanied by bones of the skeleton.

BUNOTHERIA.

TÆNIODONTA.

Additional material gives the following results with regard to the affinities of this sub-order. There are three allied groups represented by the genera *Esthonyx*, *Tillotherium* and *Calamodon* of the American Eocenes, which are equally unlike each other. *Esthonyx*, as I long since showed, is related to the existing *Erinaceus*; very nearly indeed, if the dentition alone is considered. Its anterior incisor teeth are unusually developed, and have, as in *Erinaceus*, long roots. One pair at least in the lower jaw has enamel on the external face only, and enjoys a considerable period of growth. The genus *Tillotherium* is (fide Marsh) quite near to *Esthonyx*. Its molars and premolars are identical in character with those of that genus, the only important difference being found in the incisors. Here, one pair above, and one pair below, are faced with enamel in front only, and grow from persistent pulps as in the *Rodentia*. This character has been included by Marsh in those he ascribes to his "order" of *Tillodontia*, but as he includes *Esthonyx* in that order,* which does not possess the character, it is not very clear on what the supposed order reposes. The rodent character of the incisors is the only one that I know of which distinguishes *Tillotherium* from the *Insectivora*. I have on this account retained the *Tillodonta* as a sub-order, and referred *Esthonyx* to the *Insectivora*.

The *Tæniodonta* agree with the *Tillodonta* in the possession of a pair of inferior incisors of rodent character, but it adds several remarkable peculiarities. Chief among these is the character of the inferior canines. In the *Tillodonta* they are either wanting, as in *Erinaceus*, according to the Cuvierian diagnosis, or they are insignificant. In *Calamodon* they are of large size, and though not as long-rooted as the second incisors, grow from presistent pulps. They have two enamel faces, the anterior and the posterior, the former like the corresponding face of the rodent incisors.

* Report of U. S. G. Survey 40th Parallel, by Clarance King; Vol. i, p. 377.

The function of the adult crown is that of a grinding tooth. This character distinguishes *Calamodon* as a form as different from *Tillotherium*, as the latter is from *Esthonyx*. There are, however, other characters. The external incisors, wanting in *Tillotherium*, are here largely developed, and though not growing from persistent pulps have but one, an external band-like enamel face. Their function is also that of grinders.

The fact that the rodent teeth in the lower jaw are the second incisors, renders it probable that those of the *Tillodonta* hold the same position in the jaw. This is to be anticipated from the arrangement in *Esthonyx*, where the second inferior incisors are much larger than the first and third. The superior dentition of the *Tæniodonta* is yet unknown.

CALAMODON SIMPLEX Cope.

Report Vertebrate Foss., New Mexico, U. S. Geog. Surv. W. of 100th Mer. 1874, p. 5. Report of do. Capt. G. M. Wheeler, IV, ii, p. 166.

A nearly complete mandible of this species was found by Mr. Wortman, besides a series of unworn molar and canine teeth of a second individual, and fragments of some others. These furnish the correct dental formula as far as they go, as follows: I. 3; C. 1; M. 5. It appears that I correctly referred the long rodent teeth to the lower incisior series, but that the truncate two banded teeth so characteristic of the sub-order, are canines and not incisors, and that they belong to the lower as well as probably to the upper jaw.

The characters of the incisors are very peculiar. The first are small with short subcylindric crowns, and conic roots. The second incisors have been described; as in *C. arcamænus* they have a horizontal shoulder posterior to the base of the cutting portion. The third incisors increase in diameter upwards, and have a triangular section. The largest side of the triangle is interior, and the shortest the posterior, and neither possess any enamel. The anterior or enamel faced side is slightly convex. The grinding face is transverse and is in the plane of the corresponding face of the canine. The long diameter of the crown of the canine is at right angles to the anterior face of the third incisor, and diagonal to the long axis of the mandibular ramus. This, with the peculiarities of the other incisors, gives an irregular appearance to the anterior dentition.

The five molars are very similar in character, and even those with unworn crowns do not present any distinction into premolars and true molars. The enamel covers the summit of the crown, but on wearing, it is soon reduced to a cylindrical sheath. Further wear brings the grinding surface to the anterior and posterior surfaces which are covered with cementum instead of enamel.

INSECTIVORA.

ESTHONYX BURMEISTERI Cope.

Report Vertebrate Foss., New Mexico, 1874, p. 7. Report U. S. G. G. Surv. W. of 100th Mer. G. M. Wheeler, IV, ii, p. 156, pl. XI, fig. 26.

Two fractured crania exhibit the entire dentition of this species, and give the generic characters satisfactorily. The dental formula is, I. $\frac{2}{3}$; C. $\frac{1}{1}$; P-m. $\frac{?3}{3}$; M. $\frac{3}{3}$. The first superior incisor is large, and the crown is somewhat spoon-shaped. The second incisor is as robust as the first, but the crown is shorter. The second premolar has one external and one internal lobe, in the third (fourth) premolar these lobes are much enlarged, and the tooth is transverse. The true molars have two external cusps, which are flattened, close together, and well within the margin of the base of the crown. There is one internal lobe and a strong posterior ledge, as in the opossums. Of the inferior incisors, the median is large and half gliriform, while the first and third are small. The inferior, like the superior canines, are large. The first and second (third) premolars have no internal lobes, but the second (third) has a heel. The fourth is more or less like the first true molar.

The specimens show that my original determinations of the incisors based on loose teeth were correct. They also show that this genus is not far removed from the more rodent-like genus *Anchippodus* of Leidy.

There are several species of the genus, which I define as follows:

I. Fourth inferior premolar like first true molar.

Larger; third superior premolar larger; fourth premolar with the external cusp bilobate.....*E. acutidens.*

Medium; third superior premolar smaller; fourth premolar with external cusp simple; superior incisors wide; large inferior narrower.....*E. burmeisteri.*

Medium; superior incisors narrow; large inferior wider....*E. bisulcatus.*

II. Fourth inferior premolar with anterior V open and cutting.

Smallest; incisors unknown.....*E. acer.*

A species of the size of *E. acer* has been named *E. spatularius*, but I cannot place it in the above key, as the premolar and incisor teeth are unknown. The section II, approximates nearer the genus *Conoryctes* than sect. I.

MESODONTA.

HYOPSODUS LEMOINIANUS, sp. nov.

This Mesodont is distinguished from the known species of the genus by its superior size, and the fully developed heel of the inferior third molar. The anterior inner cusps of the inferior molars are absolutely simple, and the same teeth have a weak external and no internal cingulum. The cusps are elevated and the enamel smooth.

The species of this genus known to me by their mandibles are four, and these differ chiefly in size. Their characters are as follows:

Length of true molars M. .0165; last molar elongate.....*H. lemoinianus.*

Length of true molars M. .0140; last molar longer than second.....*H. paulus.*

Size as last; last molar shorter than second.....*H. miticulus*.
Length of true molars M. .0115; last molar elongate.....*H. vicarius*.

H. lemoinianus and *H. miticulus* have not been found out of the localities where they were discovered, while the other two species are distributed through most of the Eocene horizons, and have been found in many localities. Of the *H. lemoinianus* Mr. Wortman found nine more or less fragmentary mandibles.

Dedicated to my friend, Dr. Victor Lemoine of Reims, well-known for his brilliant discoveries in the vertebrate paleontology of the Lower Eocene beds near that city.

HYOPSODUS PAULUS Leidy.

Thirty-eight more or less broken mandibular rami.

HYOPSODUS VICARIUS Cope.

Eleven mandibular rami. A few specimens are intermediate between this species and the last in dimensions, the inferior true molars measuring M. .0120 and .0125 in length.

PANTOLESTES CHACENSIS Cope.

Four mandibular rami. This species has the fourth premolar more robust and less trenchant than in *P. secans*, and shorter than the last true molar. In *P. secans* it is longer than the last true molar.

PANTOLESTES METSIACUS sp. nov.

A small species of the size of the *P. longicaudus*, and distinguished by several peculiarities of dentition. The two cusps composing the anterior internal lobe of the molars are quite distinct but appressed. Each one is connected with the external anterior lobe by a transverse crest as is seen in *Esthonyx*, and these enclose between them a fossa. This fossa is closed internally by the appression of the anterior inner cusps. The fourth premolar is not so large as in *P. secans*, but resembles in proportions that of *P. chacensis*. It differs from that of *P. longicaudus* in its very short heel and its large anterior basal tubercle. The latter is double, consisting of two small cusps, one within and anterior to the other. The posterior heel is distinct on both sides of the ridge that marks the median line. The posterior external lobe is V-shaped, and the posterior inner is a small cone. Between the two is a minute median tubercle. The posterior tubercles are not so elevated as in the species of *Hyopsodus*. A weak external cingulum; enamel smooth.

Measurements.	M.
Length P-m. IV, with M. I, and II; (No. 1).....	.0140
" P-m. IV.....	.0048
" M. II.....	.0048

Measurements.	M.
Width M. II	.0040
Length M. III; (No. 2)	.0050
Width "	.0030
Depth ramus at P-m. IV ; (No. 1)	.0060
" " M. III; (No. 2)	.0070

Portions of four mandibles preserved. No. 2 is a little smaller than No. 1, and No. 4 is a little larger than No. 1.

The species of *Pantolestes* may be distinguished as follows :

a. Fourth premolar trenchant everywhere, longer than second molar. Length of true molars M. .0150 ; second molar with but one anterior inner cusp.....*P. secans.*

aa. Fourth premolar with blunt heel, not longer than second molar. Length of true molars .0160 ; all with double cusps.....*P. chacensis.*
Length of true molars .0140 ; fourth premolar with minute anterior cusp, and long heel.....*P. longicaudus.*
Length of true molars .0130 ; fourth premolar with double anterior cusp, and short heel ; molars with double cusps.....*P. metsiacus.*
Length of true molars .0105 ; fourth premolar small, .0035, without anterior cusps, and with two ridges on heel ; true molars with double anterior inner cusps.....*P. nuptus.*

PANTOLESTES NUPTUS, sp. nov.

This is the last species of the genus, and is represented by a portion of a right mandibular ramus which supports three molars from the fourth to the sixth inclusive. Besides its small size, this species is distinguished by the relatively small dimensions of the fourth premolar, which is shorter than the first true molar instead of longer, as in all the other species. The well developed basin of its heel, which is bounded by a ridge on each side, distinguishes it at once also from *P. secans*, and is more distinct than in *P. chacensis ;* from the latter and *P. metsiacus* the entire absence of anterior basal lobes separates it. The well developed pair of anterior inner tubercles of the true molars shows that it cannot be an abnormal *Hyopsodus vicarius*, with which it agrees in size. The first anterior tubercle is more widely separated from the second anterior than in any of the species of the genus, and is quite as in species of *Pelycodus*. It is smaller than the second anterior inner, which equals in size the anterior outer. The heel is wide, enclosing a basin, which is bounded externally by an angular ridge. Its posterior inner angle supports a cusp, which is separated by a deep notch from the anterior inner cusp. External to it on the posterior border of the crown is a small tubercle. No basal cingula.

Measurements.		M.
Length of three molars		.010
Diameters of M. 1	anteroposterior	.004
	transverse	.003
Depth of ramus at P-m. IV		.007

Basin of the Big-Horn : J. L. Wortman.

PELYCODUS ANGULATUS Cope.

The species of this genus are, in the present state of our knowledge, best distinguished by their size.

Length of true molars on base				M. .024;	*P. pelvidens.**
"	"	"	"	M. .019;	*P. jarrovii.*
"	"	"	"	M. .017;	*P. tutus.*
"	"	"	"	M. .015;	*P. frugivorus.*
"	"	"	"	M. .012;	*P. angulatus.*

Remains of species of this genus are very common in the Wind River bad lands; they were originally found in the Wasatch beds of New Mexico, and have not yet been announced from the Bridger formation.

The *P. angulatus*, heretofore only known from New Mexico, is represented in the Big-Horn collection by five mandibular rami, and a portion of a maxillary bone with teeth.

PELYCODUS FRUGIVORUS Cope.

Two mandibles and seven separate rami represent this Mesodont.

PELYCODUS TUTUS Cope.

Four rami display the typical length of the true molars, M. .017. Three are smaller, having the molars .016 in length, while one gives .018 for the same teeth. Other portions of the skeleton will be necessary to determine exactly the specific position of these specimens.

PROSIMIÆ.

CYNODONTOMYS LATIDENS, gen. et sp. nov.

Char. gen. Derived from mandibular rami. Dental formula I. ? 0; C. 1; P-m. 2; M. 3. The premolars are counted as two, on the supposition that the anterior one is two-rooted; should it prove to be one-rooted, then the number will be three. The canines are very large and close to the symphysis, so that there do not appear to have been any incisors. The true molars have the frequently occuring three tubercles in front and a heel behind; but the arrangement is peculiar in that the three tubercles are but little more elevated than the borders of the heel, and occupy a small part of the crown. The last molar is lost from both jaws, but the space for it is about as large as that occupied by the penultimate. The fourth premolar has but two anterior cusps, and these are more elevated than those of the true molars, and the heel is narrower. The mandibular rami are not coössified.

The dental characters of this genus resemble considerably those of *Anaptomorphus* and *Necrolemur*, but the large size of the inferior canine tooth distinguishes it from both. The double anterior cusps of the fourth premolar equally distinguish it from them.

Char. Specif. The inferior true molars are subquadrate in horizontal outline, somewhat narrowed anteriorly. The concave heel is the larger part of the crown; it is only elevated into a low cusp at the posterior external angle. The anterior cusps are conic, and are in contact at the

* *Lipodectes pelvidens* Cope, Amer. Naturalist, Dec., 1881, p. 1019.

base. The external and posterior internal are of about the same size; the anterior inner is smaller and does not project so far inwards as the posterior. The fourth premolar has the posterior border of its heel serrate. The anterior cusps are elevated and moderately acute; the internal is a little less elevated than the external, and is separated from it by a deep notch. The alveoli for the anterior premolar are so close together, as to render it probable that they belong to but one tooth. They are placed somewhat obliquely to the long axis of the jaw. There is no diastema. The section of the base of the crown of the canine is a regular oval, the long diameter coinciding with the vertical diameter of the ramus.

The ramus is rather slender, but is shortened anteriorly. The boundaries of the masseteric fossa are well marked, the anterior ridge descending to below the middle line of the ramus. The mental foramen is large and is situated below the contact of the two premolars. The inferior edge of the ramus is rather thick.

Measurements.	M.
Length of dental series including canine	.0240
" premolars	.0062
" molars	.0114
Long diameter base canine	.0036
Diameters P-m. IV { anteroposterior	.0038
{ transverse	.0026
" " M. II. { anteroposterior	.0042
{ transverse	.0038
Depth of ramus at P-m. I	.0060
" " " M. III	.0068

ANAPTOMORPHUS HOMUNCULUS Cope, American Naturalist, 1882, Jan. (Dec. 30th, 1881), p. 73.

The genus *Anaptomorphus* was characterized by me in 1872,* from a mandibular ramus which exhibited the alveoli of all the teeth, three of them occupied by the teeth; viz.: the P-m. iv, and the M. i and M. ii. From the specimen the inferior dental formula was ascertained to be I. 2; C. 1; P-m. 2; M. 3. The Big-Horn collection contains a nearly entire cranium of what is probably a species of the same genus. From it the superior dentition, exclusive of the incisors, is determined to be: C. 1; P-m. 2; M. 3. The premaxillary bones are mostly broken off, but a part of the alveolus of the external incisor of one side remains.

The indications are that the external incisor was a small tooth, not exceeding the canine in size; and it was situated close to the latter. The canine is also small, and its simple crown is not more prominent than those of the premolars. The latter are separated from it by a very short diastema. The long diameter of their crowns is transverse to the long axis of the

* Proceedings American Philosophical Society, 1872, p. 554. Paleontological Bulletin, No. 8, p. 1, Oct. 12, 1872.

jaw; and each one consists of a larger external, and smaller internal cusp. The true molars are also wider than long, and support two external and only one internal cusps.

The orbits are large and are entirely enclosed behind. The frontal bone does not send inwards to the alisphenoid a lamina to separate the orbit from the temporal fossa, as is seen in *Tarsius*. There is no sagittal crest, but the temporal ridges are distinct. The occipital region protrudes beyond the foramen magnum, or at least beyond the paroccipital process, which is preserved, the condyles being lost. The otic bulla is large, extending anteriorly to the glenoid cavity. The pterygoid fossa is large, the external pterygoid ala being well developed, and extending well upon the extero-anterior side of the bulla, as in *Tarsius*. As in that genus, the foramen ovale is situated on the external side of the bulla, just above the base of the external pterygoid ala. The carotid foramen, as I suppose it to be, is situated at the apex of the bulla. The lachrymal foramen is situated anterior to, and outside of the orbit as in *Lemuridæ* generally.

The cast of the anterior part of the left cerebral hemisphere is exposed. This projects as far anteriorly as the middle of the orbits, leaving but little room for the olfactory lobes. The relations of the latter as well as of other parts of the brain will be examined at a future time. The part exposed does not display fissures, and gentle undulations represent convolutions.

The characters of this genus now known, warrant us in thinking it one of the most interesting of Eocene Mammalia. Two special characters confirm the reference to the *Lemuridæ* which its physiognomy suggests. These are, the external position of the lachrymal foramen, and the unossified symphysis mandibuli. Among *Lemuridæ*, its dental formula agrees only with the *Indrisinæ*, which have, like *Anaptomorphus*, two premolars in each jaw. But no known *Lemuridæ* possess interior lobes and cusps of all the premolars, so that in this respect, as in the number of its teeth, this genus resembles the higher monkeys, the *Simiidæ* and *Hominidæ*,* more than any existing member of the family. Of these two groups the resemblance is to the *Hominidæ* in the small size of the canine teeth. It has, however, a number of resemblances to *Tarsius* which is perhaps its nearest ally among the lemurs, although that genus has three premolars. One of these points is the anterior extension of the otic bullæ, which is extensively overrun by the external pterygoid ala. A consequence of this arrangement is the external position of the foramen ovale, just as is seen in *Tarsius*. Another point is the probably inferior position of the foramen ovale. Though this part is broken away in the cranium of *Anaptomorphus homunculus*, the paroccipital process is preserved, and has the

* In an early description of *Anaptomorphus*, Proc. Amer. Philos. Soc., 1873, the types make me say "this genus * * might be referred decidedly to the *Lemuridæ*, were it not for the unossified symphysis." It is scarcely necessary to state that *Simiidæ* should be read in place of *Lemuridæ*.

position seen in *Tarsius*, as distinguished from the *Indrisinæ*, *Lemurinæ*, *Galaginæ*, etc. In this it also resembles the true *Quadrumana*.

When we remember that the lower *Quadrumana*, the *Hapalidæ* and the *Cebidæ*, have three premolar teeth, the resemblance to the higher members of that order is more evident. The brain and its hemispheres are not at all smaller than those of the *Tarsius*, or of the typical lemurs of the present period. This is important in view of the very small brains of the flesh-eating and ungulate Mammalia of the Eocene period so far as yet known. In conclusion, there is no doubt, but that the genus *Anaptomorphus* is the most simian lemur yet discovered, and probably represents the family from which the true monkeys and men were derived. Its discovery is an important addition to our knowledge of the phylogeny of man.

Char. specif. The specimen is distorted by pressure, but its form is normally nearly round, when viewed from above or below. The extremity of the muzzle is broken away, but the alveolus of the external incisor indicates that it is short, and not prolonged as in *Tarsius spectrum*. The mandibular ramus, already described, proves the same thing. The orbits are large, but not so much so as in *Tarsius spectrum*; their long diameter equals the width of the jaws at the last superior molar teeth inclusive. The supra-orbital borders project a little above the level of the frontal bone, which is concave between their median and anterior parts. The cranium is wide at the postorbital region, in great contrast to its form in the *Adapidæ*, resembling the *Necrolemur antiquus* Filh. in this respect. The postfrontal processes are wide at the basal portion, and flat. From their posterior border the temporal ridges take their origin. These converge posteriorly and probably unite near the lambdoidal suture, but this part of the skull is injured. The anterior lobes of the cerebral hemispheres are indicated externally by a low boss on each frontal bone.

The paroccipital process is short and wide at the base, and it is directed downwards and forwards. The alisphenoid descends so as to form a strong wall on the anterior external side of the otic bulla. This is also the case in *Tarsius spectrum*, but in the extinct species the descending ala is more robust, and has a thickened margin. On the latter the external pterygoid ala rests by smooth contact of its thickened superior edge. This ala is twice as prominent as the internal pterygoid ala. The posterior nareal opening is not wide, and its anterior border is parallel with the posterior border of the last superior molar teeth. The palate is wide, and its dental borders form a regular arcade as in man, being quite different from the form usual in monkeys and lemurs, including *Tarsius*. Perhaps the form is most like that of *Microrhynchus laniger*. The proximal parts of the malar bone are prominent, and overhang the maxillary border, as in *Tarsius*.

The *foramina ovale* and *lachrymale* are rather large. There are two infraorbital canals, lying beside each other, and issuing by two foramina externa. The external appearance justified this conclusion, but the fact

was demonstrated when I accidentally broke away the anterior border of one of the orbits. This displayed the two canals filled with matrix their entire length. The anterior foramen externum is anterior to and above the posterior, and both are above the first (third) premolar tooth. The lachrymal foramen is above the space between that tooth and the canine.

The crown of the canine tooth is a cone with a very oblique base, and a convex anterior face. The base rises behind, and the posterior face has on the median line a low angular edge. The internal cone of the third (first) premolar is not so prominent as that of the second, though large. The external cusps of both premolars rise directly from the external base. They are flattened cones, with anterior and posterior cutting edges. The crowns are a little contracted at the middle, so as to be narrower than the inner lobe of the tooth, which is narrower than the external portion. Both premolars have delicate anterior, posterior and external cingula. The external cusps of the true molars rise directly from the external base, and like those of the premolars, have a regularly lenticular section. At the internal base of each one is a small intermediate tubercle, which is connected by an angular ridge with the single internal cusps. There are delicate anterior, posterior, and external cingula, but no internal. The posterior cingulum shows a trace of enlargement at its inner part, which is well marked on the second molar, but it is not as prominent as in many Creodont genera. The posterior external cusp of the last true molar is reduced in size. Taking the molars together, the first true molar is the largest, and they diminish in size both anteriorly and posteriorly. The third true molar is a little smaller than the first (third) premolar. Enamel smooth.

Measurements.	M.
Length of cranium to occipital prominence above par-occipital process, and minus premaxillary bone. .	.0280
Total width at posterior border of orbit, below.	.0240
Length of palate from front of canine tooth.	.0116
Width of palate and peunltimate molars.	.0125
Length of superior molar series.	.0095
" " true molars.	.0060
Diameters of crown of canine { anteroposterior.	.0018
{ vertical.	.0018
Diameters crown of P-m. iii, { anteroposterior.	.0020
{ transverse.	.0026
Diameters crown of P-m. iv, { anteroposterior.	.0020
{ transverse.	.0035
Diameters M. ii, { anteroposterior.	.0032
{ transverse.	.0040
Diameters M. iii, { anteroposterior.	.0016
{ transverse.	.0028
Diameters of orbit { anteroposterior.	.0110
{ vertical (? depressed).	.0078
Interorbital width (least).	.0050

PROC. AMER. PHILOS. SOC. XX. 111. T. PRINTED MARCH 13, 1882.

The *Anaptomorphus homunculus* was nocturnal in its habits, and its food was like that of the smaller lemurs of Madagascar and the Malaysian islands. Its size is a little less than that of the *Tarsius spectrum*. The typical specimen was found by Mr. J. L. Wortman in a calcareous nodule in the Wasatch formation of the Big-Horn basin, Wyoming Territory.

Creodonta.

Shortly after the publication of my arrangement of the Creodonta in 1880*, I obtained a good deal of additional material, which enabled me to improve it in several respects. A number of genera have been added, and the characters which distinguish the *Miacidæ* and *Oxyænidæ* have been more fully brought out. The *Miacidæ* differ from all other families in having the fourth superior premolar sectorial as in the true *Carnivora*, while the true molars are tubercular. In *Oxyæna*, the fourth superior premolar displays no indication of sectorial structure, the first true molar assuming that character. In *Stypolophus* and allies, the second superior true molar is more or less sectorial, and the first true molar and even the fourth premolar in some of the genera, develop something of the same character. But there is every gradation between the triangular *Didelphys*-like, and the sub-sectorial *Pterodon*-like forms of the superior molars, in this group of genera.

The glenoid cavity of the squamosal bone presents differences in the various genera of this sub-order. In *Arctocyonidæ* (fide De Blainville), *Oxyænidæ*, and *Mesonychidæ*, it is bounded by a transverse crest anteriorly, as well as by the postglenoid posteriorly, while in the *Leptictidæ* it is plane and open anteriorly. In *Amblyctonidæ* its condition is unknown. In existing *Carnivora* this character is not very constant as a family definition; it is best marked in the *Felidæ*, and least marked in the *Canidæ*. Nevertheless there is a group of genera allied to the *Oxyænidæ*, which are very marsupial in character, which have been called the *Leptictidæ*, and which differ so far as known from *Oxyæna* in the absence of the preglenoid crest. I suspect that these forms constitute a family by themselves, and for the present, until our knowledge of them is fuller, I define it by this character. The definitions of the families will then be as follows:

I. Ankle-joint plane transversely, or nearly so.

True molars above and below, tubercular; last superior not transverse.... *Arctocyonidæ*.

Superior true molars, tubercular; last superior premolar sectorial; first inferior molar "tubercular sectorial"... ..... *Miacidæ*.

Superior last molar transverse; inferior molars tubercular-sectorial or with reduced anterior cusp; no preglenoid crest..... *Leptictidæ*.

Last superior molar trenchant, transverse; first superior true molar sectorial; inferior true molars tubercular-sectorial; a preglenoid crest... *Oxyænidæ*.

*Proceedings Amer. Philos. Society, p. 76.

Last superior molar longitudinal; inferior true molars without developed sectorial blade.....*Amblyctonidæ*.

II. Ankle-joint tongued and grooved, or trochlear.

Molar teeth in both jaws consisting of conic tubercles and heels; none sectorial; a preglenoid crest.....*Mesonychidæ*.

I now give the characters of the genera. All these are derived from examination of typical specimens. The opportunity of doing this I owe to the kindness of Messrs. Leidy, Gervais, Gaudry, Filhol, and Lemoine.

ARCTOCYONIDÆ.

Premolars, $\frac{4}{4}$; the first inferior one-rooted; the last inferior well developed; *Arctocyon* Blv.

Premolars below, 4, the first two-rooted, the last true molar much reduced; (fide Lemoine).....*Hyodectes* Cope.

Premolars below, 3, first two-rooted; true molars normal.....*Heteroborus* Cope.

MIACIDÆ.

Inferior tubercular molars two, premolars four.....*Miacis* Cope.

Inferior tubercular molars one, premolars four.....*Didymictis* Cope.

LEPTICTIDÆ.

I. Superior molars sub-equilateral, without cutting heel posteriorly.

a. Fourth inferior true molar like the true molars, with three anterior cusps.

β. Third superior premolar with internal cusp; anterior cusp of inferior molars small, median.

Third premolar with one external and one internal cusps.*Mesodectes* Cope.

Third premolar with two external and one internal cusps....*Ictops* Leidy.

ββ. Third superior premolar without internal cusps; anterior cusps of inferior molars present.

Cusps of superior molars marginal; two superior incisors; *Leptictis* Leidy.

Cusps of superior molars median in position; anterior cusp of inferior molars well developed.....*Peratherium* Aym.

βββ. Anterior cusps of inferior molars wanting.

Fourth inferior premolar like true molars.....*Diacodon* Cope.

aa. Fourth inferior premolar different from true molars in a simpler constitution.

Last inferior molar tubercular; cusps of other true molars well developed; three inferior premolars.....*Lipodectes* Cope.

Inferior true molars alike, with anterior inner cusps little developed; three premolars (?).....*Trisodon* Cope.

Inferior true molars alike, with cusps well developed; four premolars....*Deltatherium* Cope.

II. One or more superior molars, with the external heel produced into a blade.

a. Molars 4—3; three last inferior tubercular sectorial.

Premolars robust, conic.....*Quercitherium* Filh.
Premolars compressed; the fourth superior with a conic cusp and heel externally.....*Stypolophus* Cope.
Premolars compressed; fourth superior with a simple blade externally... *Proviverra* Rütim.

OXYÆNIDÆ.

I. Inferior molars without internal tubercles.

Molars, $\frac{4}{4}$ $\frac{3}{3}$; three sectorials in the lower jaw.....*Pterodon* Blv.

II. Inferior molars with internal cusps.

a. Posterior heel of one or more superior molars elongate and trenchant.

Last inferior molar truly sectorial, without internal tubercle; second, tubercular-sectorial.....*Protopsalis* Cope.
Molars, $\frac{4}{4}$ $\frac{3}{3}$; two last inferior molars tubercular-sectorial...*Oxyæna* Cope.

AMBLYCTONIDÆ.

Fourth inferior premolar with a broad heel supporting tubercles; an anterior and no internal tubercles.....*Amblyctonus* Cope.
Inferior molars with tubercular heel, an anterior and an internal tubercle. *Periptychus* Cope.
Dental formula below, 3, 1, 3, 3. Fourth inferior premolar with a cutting edge on the heel; both internal and anterior tubercles..... *Pulæonyctis* Blv.

MESONYCHIDÆ.

a. Inferior molars seven;

Cones of inferior and superior molars simple.....*Mesonyx*.
Cones of last two inferior molars with lateral cusps.....*Dissacus*.

aa. Inferior molars ? six.

Internal lobes of penultimate superior molar v-shaped.:...*Sarcothraustes*.

aa. Inferior molars five.

Inferior molars with strong anterior lobe.....*Patriofelis*.*

MIACIS CANAVUS Cope.

Bulletin U. S. Geol. Survey, Terrs., 1881, p. 189. One mandible.

MIACIS BREVIROSTRIS Cope, loc. cit. p. 190.

Parts of four mandibles.

DIDYMICTIS DAWKINSIANUS Cope, l. c., p. 191.

Six mandibular rami more or less complete.

Individuals of the genus *Didymictis* are abundant in the Wasatch beds

* Of uncertain reference to this family.

of the Big-Horn, and a good many of them do not coincide well in characters with the species already described. I define them as follows, premising that with other parts of the skeleton some changes may be found to be necessary. The large *D. altidens* was not obtained by Mr. Wortman in the Big-Horn country.

I. Inferior tubercular molar oval in outline, with a heel.

Length true molars .010 ; last three premolars .0135 ; last molar narrow.. *D. dawkinsianus.*

Length true molars .016—.018 ; last three premolars .028—.030 ; last molar narrow..... *D. leptomylus.*

Length true molars .019—.020 ; last three premolars .036 ; last molar elongate..... *D. protenus.*

Length true molars .025 ; last three premolars .035 ; last molar short..... *D. altidens.*

II. Inferior tubercular molar short, subquadrate in outline.

Length true molars .011 ; depth of ramus at sectorial .010..... *D. masseterícus.*

Length true molars .018 ; depth of ramus at sectorial .017....*D. curtidens.*

DIDYMICTIS LEPTOMYLUS Cope.

American Naturalist, 1880, p. 908.

The specimens which I refer at present to this species belong to two varieties, which may perhaps be specifically distinct ; but this cannot be demonstrated at present. They differ in dimensions only. Thus the true molars of the type, which comes from the Big-Horn beds, measure M. .016 in length. Five specimens from the Big-Horn basin agree in having this dimension .018. The entire inferior molar series is only a little shorter than that of the smaller variety of the *D. protenus* from New Mexico (See my report to Capt. Wheeler, plate XXXIX).

DIDYMICTUS PROTENUS Cope.

Jaws more or less complete, of six individuals, are referable to this species. They agree closely in measurements and belong to the larger variety of the species figured on plate XXXIX of the report to Capt. Wheeler.

DIDYMICTIS MASSETERICUS, sp. nov.

This species is intermediate in size between the *D. leptomylus* and the *D. dawkinsianus*, and is characterized by the peculiar form of its tubercular molar, and the deeply excavated masseteric fossa. It appears to have been a rare species, as only one mandibular ramus was found by Mr. Wortman. This is broken off in front of the fourth premolar, and supports the last true molar teeth.

The tubercular molar is subquadrate in form, and consists of three low tubercles in front, and a wide heel behind, which has an elevated posterior border. The tubercular-sectorial has a short and narrow heel. Its anterior cusps are not very acute, and the two internal are equal, and a good deal

shorter than the external. The fourth premolar is relatively shorter than in any other species of the genus, and the posterior marginal lobe is a mere thickening of the edge of the heel. There is a low anterior basal tubercle. The enamel is smooth.

The ramus is compressed and not deep. The angle is prominent, and is not inflected; it does not extend so far posteriorly as the posterior border of the condyle. The inferior border of the masseteric fossa is an angular line, without abrupt excavation, but the face of the fossa descends rapidly. The anterior border of the fossa is abrupt and is formed by the usual subvertical ridge.

Measurements.	M.
Length between P-m. IV, and condyle inclusive	.0520
" of posterior three molars	.0170
" of tubercular-sectorial	.0070
Elevation of " "	.0070
Depth of ramus at sectorial	.0100

DIDYMICTIS CURTIDENS, sp. nov.

As in the case of the *D. massetericus* the present species is represented by a single fragmentary mandibular ramus. This supports a sectorial tooth of the size and form of that of the *D. protenus*, and is thus much larger than that of the species just named. This tooth is placed nearer to the base of the coronoid process than is seen in any other species, and only leaves space for a short tubercular tooth. This is lost from the specimen, but the alveolus shows pretty clearly its dimensions. The base of the fourth premolar remains, and it is evident that this tooth was like that of *D. protenus* in form and proportions. The base of the posterior marginal lobe is present. The ramus is deeper and larger than in the *D. massetericus*.

Measurements.	M.
Length of bases of last three molars	.0285
" " fourth premolar	.0120
" " sectorial on base	.012
Width " in front	.008
Depth of ramus at sectorial	.017

ICTOPS BICUSPIS Cope. Bull. U. S. Geolog. Surv., Terrs. 1881, p. 192.

This mammal was founded on a skull from the Wind River region. It is now represented by a mandibular ramus. The form of the fourth premolar being unknown, its reference to this species is provisional only. It may be remotely allied to *Stypolophus*, but the anterior inner cusp of the molars is small and does not reach the inner side of the crown, and the anterior external cusp is but little larger than the second anterior inner. The two cusps last named stand opposite to each other, and their apices are only separated from each other by an open notch. They, with the first anterior inner (here median), form a transverse narrow triangle. The posterior part of the crown is rather large and, though lower than the anterior part,

is absolutely quite elevated above the alveolar border. Its summit presents a V externally, and there is a small posterior median angle. In the last true molar this angle is a little more prominent than in the others, and rises into a cusp. The external bases of the crowns are protuberant, but there are no cingula. Enamel smooth.

The ramus is rather compressed, and the masseteric fossa is well marked, and is bounded anteriorly by a prominent rib.

Measurements.		M.
Length of true molars		.0100
Diameters M. III	anteroposterior	.0035
	vertical	.0035
	transverse	.0030
Diameters M. I	anteroposterior	.0035
	transverse	.0028
Depth of ramus at M. II		.0070

This species is smaller in all dimensions than *I. didelphoides*, and the crowns of the molar teeth are shorter and more elevated than in that species.

DELTATHERIUM ABSAROKÆ Cope. American Naturalist, 1881, p. 669.

A small species, represented by an imperfect cranium and lower jaw with nearly complete dentition.

STYPOLOPHUS ACULEATUS Cope.

Several fragmentary mandibles nearly coincide in measurements with this species. The molars are .0240 in length, and the ramus is .0140 in depth. The only difference in the measurements is that the true molars measure .0250 in *S. aculeatus*. The latter is, however, a species of the Bridger epoch, so that further comparison will be necessary before identification is made.

STYPOLOPHUS WHITIÆ, sp. nov.

Stypolophus strenuus Cope. Bulletin U. S. Geol. Survey, VI, 192; not of Report Capt. Wheeler, vol. IV, pt. ii.

The greater part of the skeleton, with skull and dentition of this species, were brought from the Big-Horn by Mr. Wortman. A part of a mandible of a second individual was also found. The species is, however, primarily based on a specimen from the Wind river. This is represented by a right mandibular ramus which supports all the molar teeth, and displays the alveolus of the canine, and lacks all posterior to the coronoid process; also by a portion of the frontal bone, two vertebræ, fragments of scapula, humerus, ulna, radius, ilium, and tibia, and the greater part of both tarsi. They represent a species larger than the Virginian opossum, and intermediate between the *S. brevicalcaratus* and *S. strenuus* in proportions. It has not the rudimental heels of the molars of the former species, nor the robustness of the latter.

The inferior outline of the mandible is gently curved from the canine

to below the last molar. The anterior border of the masseteric fossa is well marked, but not the inferior border. The ramus is compressed and deep. The canines have stout roots and narrow curved crowns. The first premolar is separated by a short space from the canine and by a longer one from the second premolar. It has either a single compressed root or two roots confluent within the alveolus. The crown is truncated obliquely behind. The second premolar is two-rooted and the crown is elevated anteriorly and depressed posteriorly. The third premolar is more symmetrical, but the heel is produced. It is narrow and keeled medially. The fourth premolar is abruptly larger than the third. Its crown is simple, except a low tubercle at the anterior base and a short trenchant heel at the posterior base. Of the three tubercular-sectorials the first is the smaller. The heels of all three are rather narrowed and elongate. Their margin is raised all round, inclosing a basin; a notch in the external margin cuts its anterior part into a tubercle. The two internal tubercles are rather obtuse, and are considerably shorter than the external cusp.

Measurements.	M.
Length from canine to end of last molar	.060
" " " first true molar	.037
" " " second premolar	.015
" of base of fourth premolar	.009
Elevation of fourth premolar	.007
Length of base of second true molar	.007
" heel " " "	.006
Elevation of second true molar	.009
Depth of ramus at third premolar	.015
Length of superior canine	.028
" crown of superior canine with enamel	.012

A portion of the frontal bone shows weak anterior temporal ridges uniting early into a sagittal crest, which is low as far as preserved. The parietal bones overlap the frontal as far forwards as the temporal ridges. Anterior to the latter the front is concave in transverse section. Viewed from below, the spaces for the olfactory lobes are large and entirely anterior to those which received the anterior lobes of the hemispheres; each one is about as wide as long. In the small part of the cerebral chamber wall left, there is no indication of convolutions, which would be visible in a gyrencephalous brain; two air-chambers in front of each olfactory lobe.

The base of the transverse process of the atlas is perforated from behind to the middle of its inferior side; from the latter opening a foramen penetrates directly into the neural canal. A posterior dorsal vertebra has the centrum longer than wide and much depressed. Its inferior face is regularly convex in section. The proximal end of the scapula shows that its inner border is much thickened, and that the spine arises abruptly and near to the glenoid cavity. There appears to have been scarcely any coracoid; the surface adjoining it is, however, injured. The humerus lacks

the proximal portion and the inner half of the condyles with the epicondyles. The deltoid crest is not very prominent, so that the shaft is rather slender. The external distal marginal crest is thin, and is continued well up on the shaft. The external part of the condyle displays no intertrochlear ridge. Olecranar and coronoid fossæ well marked. The olecranon is robust and deep, and is truncate posteriorly and below. The head of the radius is a regular transverse stout oval.

A fragment of the ilium from near the acetabulum displays a prominent "anterior inferior spine." The best preserved tarsus includes calcaneum, astragalus, cuboid, and navicular bones. The tibial face of the astragalus is strongly convex antero-posteriorly and slightly concave transversely. The head is prolonged some distance beyond the distal extremity of the calcaneum, and presents a convex internal border and a concave external one. Its long axis is parallel to that of the tibial portion, but is not in the same axis, owing to its lateral position. The external face of the trochlear portion is vertical, and is interrupted by a deep fossa behind. The internal face is very oblique, and becomes the superior face of the head. The posterior face of the trochlea is grooved with a wide and shallow groove, which just reaches the superior face, terminating on the external side. The superior face is not grooved, but is shallowly concave in transverse section. The head is a transverse oval, and is convex; it has a small facet for the cuboid on the outer side.

The heel of the calcaneum is large and expands distally, so as to be as wide as deep. The convex astragalar facet is very oblique to the long axis of the calcaneum; the sustentaculum is rather small. Below the latter is a narrow tuberosity looking downwards and forwards. On the external side, close to the cuboid facet, is a depressed crest. The cuboid facet is as deep as wide. The cuboid bone is a little longer than wide proximally, and narrows distally. It has a narrow astragaline facet and a deep fossa below proximally. The hook inclosing the groove for the tendon of the flexor muscle is prominent. The navicular is rather small, and has three inferior facets, which diminish in size outwards. It has a strong posterior knob-like process, with a narrow neck.

When the tarsal bones are in position, and the tibia stands vertically on the astralagus, the cuboid bone is turned inferiorly. This indicates that this species walked on the outer edge of the hinder foot.

Broken metapodial bones are slender and straight. The proximal end of a metacarpal does not display the interlocking lateral articulation seen in *Protopsalis*. Two phalanges are depressed in form.

Measurements.		M.
Diameters of a dorsal centrum	anteroposterior	.0145
	vertical	.0075
	transverse	.0115
Diameters of glenoid cavity scapula	anteroposterior	.0145
	transverse	.0090

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Measurements.	M.
Depth of olecranon	.0110
Width of head of radius	.0110
" neck of ilium anteroposteriorly	.0120
Diameter of shaft of tibia at middle	.0085
Diameters of astragalus: anteroposterior greatest	.0180
Diameters of astragalus: transverse, of trochlea	.0140
Diameters of astragalus: transverse, of head	.0100
Length of head	.0070
" calcaneum	.0300
Width of calcaneum at sustentaculum	.0140
" cuboid facet	.0066
Length of cuboid	.0120
Diameters: anteroposterior, distal	.0070
Diameters: anteroposterior, proximal	.0075
Diameters: transverse proximal	.0098
Diameters of navicular: vertical	
Diameters of navicular: transverse, with tuberosity	.0100
Diameters of navicular: transverse, without tuberosity	0070
Diameters of navicular: anteroposterior	

As already remarked, it is probable that the semigrooved trochlea of the astragalus of this species is an indication that the genus *Prototomus* must be retained as distinct from *Stypolophus*, to which the present species probably truly belongs.

The specimen described, together with the mandibular ramus of another supporting the last two molar teeth, were found in the bad lands of Wind river, Wyoming, by J. L. Wortman. Dedicated to Frances Emily White M. D., of Philadelphia.

OXYÆNA FORCIPATA Cope.

Report Vert. Foss., New Mexico, 1874, p. 12. Report Capt. G. M. Wheeler, U. S. G. G., Expl. Surv. W. of 100th Mer. IV, ii, p. 105, 1877.

This formidable animal was abundant in Northern Wyoming, during the Wasatch epoch. At least ten individuals are represented in the collection. The following are the dimensions of the mandibles of the five best preserved.

	1	2	3	4	5
Length of dental series	.103	?	.100	.100	.107
" premolar "	.042	.045	.044	.051	.054
Depth of ramus at M. III	.042	.039	.037	.042	.047

The measurement .035 for the length of the premolars given in my report to Capt. Wheeler, loc. cit., refers to the anterior three teeth, which were originally supposed to be the only premolars.

The claws of this species are moderately compressed, and they terminate abruptly and obtusely. The extremity is deeply fissured, and each of the two apices is rugose.

MESONYX OSSIFRAGUS Cope, American Naturalist, 1881, p. 1018.

Pachyæna ossifraga Cope. Report Capt. Wheeler, U. S. G. G. Surv. W. of 100th Mer. IV, ii, p. 94, 1877.

A series of specimens of this species demonstrates the following points: (1) *Pachyæna* was founded on a superior molar of *Mesonyx*, and must be suppressed. (2) *Mesonyx navajovius* Cope must be separated as a distinct genus, since the apices of the crowns of the last two molars have two cusps. I have called this genus *Dissacus* (American Naturalist, Dec., 1881). (4) It results that there are three species of *Mesonyx*: *M. ossifragus* Cope, *M. lanius* Cope, and *M. obtusidens* Cope.

M. ossifragus was the largest Creodont of the Eocene, equaling the largest grizzly bear in the size of its skull. In a cranium with lower jaw and almost complete dentition, the length to the premaxillary border from the postglenoid crest is M. .365; the largest *Ursus horribilis* in my collection gives .270 for the same length. This specimen has the dental formula I. $\frac{3}{3}$; C. $\frac{1}{1}$; P-m. $\frac{4}{4}$; M. $\frac{3}{3}$. The claws have the flattened form which I discovered in *M. lanius*, and the proximal phalanges have much the shape of those of a Perissodactyle. The astraglus has much the character of the animals of that order, and has the distal facets as I originally detected them in the *M. obtusidens*. The form of this bone is rather shorter and wider than in the latter species.

The inferior canine tooth of a large specimen has the following diameters at the base of the crown: anteroposterior .039; transverse .024.

AMBLYPODA.

PANTODONTA.

The explorations in the bad lands of the Big-Horn river yielded several species of this sub-order, all which I refer at present to the *Coryphodontidæ*. They, however, represent several genera, two of which have not been previously known. I have distinguished these (American Naturalist, Jan., 1882), in the characters of the superior molar teeth as follows:

I. Last superior molar with two interior cusps.

All the superior molars with a well marked external posterior V..... *Manteodon.*

II. Last superior molar with but one inner cusp or angle.

a. Last superior molar with posterior external cusp.

Anterior two molars with posterior external V..... *Ectacodon.*

aa. Last superior molar without external posterior cusp.

† Anterior two molars with posterior external V.

Astralagus transverse, with internal hook..... *Coryphodon.*

Astragalus subquadrate, without internal hook..... *Bathmodon.*

†† First superior molar only with posterior external V..... *Metalophodon.*

The type of *Manteodon* is the *M. subquadratus*, which was about the size of an ox. The characters of its superior molars are more like those of Perissodactyles than are those of the other *Coryphodontidæ*. The type of *Ectacodon* is the *E. cinctus*, a species of about the dimensions of the last named. Its last superior molar is parallelogrammic, and has a cingulum all around it except on the external side.

MANTEODON SUBQUADRATUS, gen. et sp. nov.

Char. gen. These have been already pointed out in the key above given. They are a little more like those of the superior molar teeth of such *Perissodactyla* as *Limnohyus* and near allies, than those seen in the typical *Coryphodon*. The posterior transverse crest of that genus is here represented by a complete V, but the anterior lobe of that crest which represents the anterior V of the Perissodactyle, is only a lobe, as in *Coryphodon*. The tooth in fact is much like the penultimate molar of the latter genus. The two internal cusps are unique in the family. The additional one is a growth of the inner extremity of the posterior cingulum, and is separated from the anterior inner cusp by a deep and wide notch. It is opposite to the posterior V, as the anterior inner cusp is opposite the anterior rudimental V. The premolar and incisor teeth are similar to those of *Coryphodon*. The skeleton is unknown.

Char. specif. These are learned from a series of teeth which were found together by Mr. Wortman free from admixture of others. They are not worn, excepting by moderate use of the animal when living.

The last superior molar is not of the oval form belonging to the species of *Coryphodon*, but is quadrate, with the internal side shorter and with rounded lateral angles. The first anterior cingulum, which represents the anterior basal cingulum of the *Lophiodontidæ*, is as elevated as in the species of *Coryphodon*. Externally it rises in a protuberance with sharp edge, which curves posteriorly and disappears on the external side of the crown. The inner extremity terminates abruptly, forming the anterior interior tubercle. The anterior external lobe is rather flat, and is not conical nor elevated above the anterior cingular lobe. It is not deeply separated from the latter, nor from the posterior V; its edge is rough. The posterior V projects well inwards, and is rather narrow. Its posterior border extends as far outwards as the point of junction of its anterior border with the anterior external lobe, and terminates in a slight elevation of its border. The base of the crown extends external to the base of the V, and forms a strong posterior external protuberance. This causes the outline of the external base to be concave. This side of the crown has several small protuberances and rugosities. The posterior basal cingulum extends as far externally as the posterior V, and terminates internally in the posterior internal cusp. The second or basal anterior cingulum is well developed. There are no external nor internal cingula. The surface of the enamel is strongly and closely rugose where not worn.

The posterior inferior molar exhibits a transverse posterior crest, without

any tubercle or ridge in the mouth of the posterior V-shaped valley. There is a strong posterior cingulum, amounting to a narrow heel. As in the case of the superior molar, the enamel where not worn is closely and strongly wrinkled. The first superior premolar is characterized by the very small development of its internal lobe, which is only a strong basal cingulum. The crown proper has a sub-triangular outline, and the external face is flat and not concave. No external cingulum; enamel wrinkled. An external incisor has a large transversely extended crown, without cingula. A low rib on the median line of the inner side. Enamel wrinkled. In this and in another incisor, the base of the crown is considerably expanded laterally.

Measurements.		M.
Diameters of crown M. III, sup.	anteroposterior	.035
	transverse	.041
	vertical	.020
Width of M. III inferior, posteriorly		.022
Diameters P-m. I sup.	anteroposterior	.018
	transverse	.014
Diameter base crown I, II		.024
Length crown I, II		.019
Width base crown I, III		.026

ECTACODON CINCTUS, gen. et sp. nov.

Char. gen. In *Ectacodon* the last superior molar has more of the elements of a posterior external V than in *Coryphodon*, but not so much as in *Manteodon*. The posterior transverse crest, it is true, has no oblique posterior ridge joining it, to form with it more or less of a V. But the external posterior angle of the crown supports a cusp, homologous with the vertical rib found at the basal or external angles of the Vs in *Palæosyops* and allied genera, and indicating the outlines of a V which lacks its posterior side, in a manner not seen in *Coryphodon*. The penultimate and ante-penultimate superior molars are like those of the latter genus. Skeleton unknown. I have a single species of this genus.

Char. specif. Six superior molars of one skull represent this species. They belong to a large animal, one about the size of the *Manteodon subquadratus*. The last superior molar has a characteristic outline. It is not oval as in the species of *Coryphodon*, nor quadrate as in *Manteodon* sp., but sub-parallelogrammic. The transverse diameter exceeds the anteroposterior, and the anterior and posterior sides are parallel. The external outline is slightly oblique and slightly notched in the middle. The internal border is regularly rounded. The basal or second cingulum extends entirely round the tooth from the posterior external cusp, round the inner base to the anterior external base of the crown; being absent only from the external base. The first cingula both anterior and posterior are well developed as in the species of *Coryphodon*, and unite in the prominent internal angle. The posterior first cingulum joins the posterior basal cin-

gulum at the middle of its length. The anterior first cingulum extends to the anterior external part of the crown, and then turns downwards and posteriorly and terminates at the middle of the external base. The posterior crest is not transverse, but quite oblique, sloping at an angle of 45° with the axis of the jaw. The part of the crest which represents the posterior V is a good deal larger than the part representing the anterior V, and is closely joined with it. The latter is well separated from the anterior first cingular ridge and its anterior exterior elevated portion. The enamel of this tooth is finely wrinkled, and is more readily worn smooth than in the *Manteodon subquadratus*.

The penultimate superior molar has the posterior V well developed, and its posterior basal or external angle is marked by a tubercle homologous with that which is so prominent on the last molar. The anterior V is a conic tubercle closely joined with the posterior V, and well separated from the anterior first cingular lobe. The basal cingula are well developed, but do not meet on the inner base of the crown. The first or superior cingula meet as usual in an interior angle, but there is a contraction of the anterior crest just before reaching this angle. The first true molar is smaller than the second and has the same general structure. Here, however, the anterior first cingulum is more prominent near the internal angle than the posterior. The characters of the premolars do not differ from the corresponding ones of species of *Coryphodon*. The enamel is delicately wrinkled. The first superior premolar is not preserved.

Measurements.		M.
Diameters of crown of M. III	anteroposterior	.034
	transverse	.043
	vertical	.015
Diameters M. I	anteroposterior	.028
	transverse	.033
	vertical	.012
Diameters P-m. III	anteroposterior	.023
	transverse	.030

It is probable that this species was about the size of an ox.

CORYPHODON ANAX, sp. nov.

Mr. Wortman sends me a number of teeth of probably two individuals, which exceed in size those of any species of *Coryphodon* yet known, and differ in certain details of form from all of them. The specimens consist of incisors, premolars and molars of both jaws of one animal, and an inferior canine, which from its separate wrapping, I suppose to have been derived from a different locality.

The incisors and premolars have the form usual in species of the genus, differing only in their large size. The same may be said of the premolars. A well preserved superior true molar is probably the third. It has the form usual in the genus, but exhibits two peculiarities. The posterior transverse crest is divided more deeply than usual by a deep notch which

enters it from the transverse valley. The external portion is the shorter, and exhibits the peculiarity of being connected with external part of the anterior transverse crest. It is as closely connected with this crest, as it is with the internal portion of the posterior crest. The external connection does not exist in the other species of the genus, where the two crests are separated at their outer extremities by a deep valley. The posterior basal cingulum is obsolete, while the anterior is well developed. The enamel of this tooth where not worn, is wrinkled.

The posterior part of the last inferior molar is characteristic. The posterior transverse crest is short and very oblique, its inner extremity striking the posterior margin near the middle. Here it is elevated into a cusp, which rises above the surrounding parts in a characteristic manner. There is no ledge round its posterior base, but the border expands outwards at the base of the true crest. The additional inner marginal tubercle is low and compressed as in *C. lobatus*. A second inferior true molar is normal, with well developed anterior marginal ridge. The inferior canine mentioned is of large proportions, exceeding by one-half the dimensions of the inferior canine of *C. lobatus*. Its crown is curved outwards, and has a basal alate expansion of its internal ridge.

Measurements.		M.
Diameters of last superior molar	anteroposterior	.039
	transverse	.051
Diameters of second inferior true molar	anteroposterior	.039
	transverse	.028
Length of inferior canine		.160
" crown of "		.090
Diameters of base of crown of canine	vertical	.037
	transverse	.036

This species is nearest the *C. lobatus* in some respects. The short posterior crest of the last inferior molar with its cusp-like extremity, and the absence of posterior ledge on this tooth will readily distinguish it.

Bad lands of the Big-Horn river, Wyoming.

There are six individuals of this species in the collection which are mostly represented by fine specimens, which represent the entire dentition.

Eight other species of *Coryphodon* were obtained by the Big-Horn Expedition, and the material enables me to distinguish them better than heretofore. I present the following differential synopsis of their characters:

I. The last inferior molar with three posterior cusps, the internal sometimes represented by a ridge; or the posterior inferior molars with an accessory cusp or tubercle on the inner side between the crests (*Coryphodon*, Owen):

An internal tubercle; last upper molar with the anterior cross crest and anterior external crest closely connected; size largest..... *C. anax.*

An internal conic cusp; posterior crest oblique; heel very small; size medium.. ..... *C. cuspidatus.*

An internal crest; posterior crest oblique; heel small; size medium..... *C. obliquus.*

An internal tubercle; posterior crest little oblique; heel large; size large. *C. lobatus.*

II. Posterior inferior molars with two posterior cusps; without internal accessory tubercle:

a. Posterior inferior molars with small or no heel:

Large; posterior superior molar oval, with distinct straight posterior crest; inferior molars elongate; symphysis mandibuli produced and narrowed; premaxillary elongate..... *C. latipes.*

Medium; inferior molars nearly as wide as long; premaxillary short..... *C. latidens.*

aa. Posterior inferior molars with prominent or wide heel:

Medium; posterior superior molar with posterior angle, and angulate posterior crest; inferior molars elongate; symphysis mandibuli broad and short; premaxillary elongate; tusk trihedral.... *C. elephantopus.*

Smaller; premaxillary bone short; tusk trihedral..... *C. simus.*

Medium; premaxillary elongate; tusk compressed and grooved..... *C. molestus.*

Large; last superior molar oval, with angulate posterior crest; its anterior lobe connected with anterior cingular crest..... *C. repandus.*

III. Last inferior molar with but one posterior cusp from which a curved crest extends round the posterior border of the crown.

Superior true molars narrow; external incisors sharply angulate on external face..... *C. curvicristis.*

IV. Posterior inferior molar unknown.

Posterior superior molar oval; posterior crest straight; internal crest fissured (? normally); a complete internal cingulum... *C. marginatus.*

CORYPHODON CUSPIDATUS Cope.

This species was found in a single individual obtained in New Mexico; a second one was discovered by Mr. Wortman in the Wind River basin, and a third has now been brought from the Big-Horn.

CORYPHODON LATIPES Cope.

I refer seven individuals provisionally to this species. Three of these are represented only by superior teeth, etc., and in four the last inferior molar is preserved. Of the latter, three have an angle, sometimes almost a crest, descending from the posterior inner tubercle, as in *C. obliquus*, but the specimens are all of superior size to that species, some of them very much exceeding it. It is also possible that this ridge is not a constant character. This species has the dentition which I have referred to the *Bathmodon radians*, but no astragalus of the species occurs in the collection. It may be the *C. latipes*, of which the teeth have not yet been identified. I hope soon to be able to decide this question.

CORYPHODON SIMUS Cope.

A broken mandible and maxillary bone, with several teeth represent this small species in the Big-Horn collection.

CORYPHODON ELEPHANTOPUS Cope.

Portions of the dentition of both jaws, including the last molar teeth of two individuals, prove that this species inhabited Wyoming in the early Eocene period. One of the individuals, represented only by the last molars of both jaws, is a little smaller than the typical specimen of which an entire cranium is figured in Capt. Wheeler's report (4to, 1877, Pl. LI–III), while a second specimen, which includes the entire superior molar series, is a little larger than the same.

This species is characterized by the obliquity of the edge of the posterior crest of the posterior superior molar backwards away from a transverse line; and by the slope of the external side of this crest. In other words the inner half of the posterior crest nearly forms a V, like that of the penultimate molar. The posterior edge of the V is present, running outwards from the inner end of the posterior crest, which thus becomes the apex of the V. The *C. elephantopus* thus most nearly approaches the genus *Manteodon*, of all the species. To accommodate the obliquity of the crest the posterior outline of the last upper molar is strongly angulate, giving a sub-triangular outline. The heel of the last inferior molar is insignificant.

CORYPHODON REPANDUS, sp. nov.

This large species is known from the posterior portions of the dentition of both jaws, with an entire symphysis.

The last superior molars are intermediate in outline between the regular oval of the *C. radians*, and the sub-triangular form of the *C. elephantopus*. The peculiarities of the species are seen in the posterior crest. The two lobes of which this is composed, do not form a continuous line as in *C. latipes* and *C. simus*, but form an angle with each other as in *C. anax*. The anterior lobe is compressed, and its long axis is nearly that of the jaw; the second lobe leaves it at a right-angle, but curves backwards as it extends inwards, giving a concave exteroposterior border. There is no ridge descending outwards from the inner extremity of the crest, to form a V, as in *C. elephantopus*. But the posterior basal cingulum extends to the external side of the tooth, which is not the case in any other species known to me excepting the *C. marginatus*. The anterior cusp is closely joined to the external elevation of the anterior first cingulum as in *C. anax;* a character which separates it from all other species. A strong trace of a cingulum passes round the inner base of the crown. No external cingulum. The first true molar does not differ materially from that of other species. It is considerably smaller than the last. The apex of the premaxillary bone with the second incisor and alveolus of the first, is preserved. The bone is rather short. The crown of the incisor is regularly convex ex-

ternally, and is not expanded at the base. There is a strong internal cingulum.

A fragment of the lower jaw supports the last two molars. The internal angle of the last one, is unfortunately broken. The posterior crest is, however, perfectly transverse, which is not the case with the species with three posterior tubercles. The preserved part of the posterior border shows a distinct, rather narrow heel. The anterior Vs are well developed and there are no lateral cingula. The symphysis is flattened out by pressure. The inferior canine is large. It is sub-triangular at base and has an anterior basal angular projection.

Measurements.		M.
Diameters of superior M. III	transverse	.046
	longitudinal	.037
Diameters of superior M. I	transverse	.036
	longitudinal	.032
Diameters crown I. 2	vertical	.018
	transverse	.018
Diameters inferior M. III	transverse	.028
	anteroposterior	.040
	vertical in front (restored)	.024
Length of symphysis		.107
Depth of ramus at M. III		.056

The superior molars of this species might readily be taken for an undersized individual of *C. anax*, but the last inferior molar is of a different type, and refers the species to a different section of the genus.

CORYPHODON CURVICRISTIS, sp. nov.

The fragments which represent this species belong to one individual. They include a considerable part of both mandibular rami with numerous molar teeth, and most of the inferior incisors loose. Also the second superior molar, some superior premolars, the canine, and three or four incisors, two of them in place in an incomplete premaxillary bone. None of the bones of the skeleton were obtained, so far as known.

The ramus of the mandible is both robust and deep. Its inferior border does not rise posteriorly so much as in some species, as *e. g.*, *C. latidens*, and the angle is well below the horizontal line of the dental alveoli. The dental foramen is just about in this line. The inferior premolars and molars do not differ from those of several other species, but the last molar has several peculiarities. The external cusp is the only one of the posterior pair which is present. It gives origin to two crests, both of them curved. The posterior represents the usual posterior transverse crest, but is gently convex backwards, and turns forwards on the inner side of the crown, only terminating at the external base of the anterior cross crest. The other curved crest is low, although higher than in most species, and extends to the middle of the base of the anterior cross crest. There is a distinct heel which is elevated at the middle and disappears gradually at each end, not being abruptly incurved as in *C. anax*. The anterior part of this

tooth is as peculiar as the posterior. The external cusp gives origin to three crests, two of them the usual limbs of the anterior V; while a third descends to the anterior border a little exterior to its middle. It encloses a deep groove with the anterior ridge of the anterior V. This arrangement is not seen in any other species.

The inferior canine is robust, and has its anterior angle prominent, but not alate. The crowns of the inferior incisors are regularly convex exteriorly, and have no cingula. They are regularly graded in dimensions.

The superior molar preserved is probably the penultimate. Its anterior portion is broken. The posterior external V is narrower than usual for a second molar, and resembles somewhat that of the last superior molar of the *Manteodon subquadratus*. A slight contact face on the posterior cingulum shows that this tooth is not the last molar. The said cingulum extends to the external base of the V; in rising to the internal cusp it forms a sigmoid curve. The cingulum below this, on the inner base of the crown, is rudimental. The superior canine has a long and robust crown, with a triangular section to the apex. The posterior face is a little wider than the other two, which are equal. The anterior is slightly concave in cross-section, and the posterior slightly convex transversely, although concave longitudinally. There is a weak ridge nearly parallel to and near the postero-external angle, and traces of others on the postero-external face of the crown in front of this one. The antero-internal angle is swollen at the base.

The superior incisors present characteristic features. The ridge of the external face, which is weakly developed in some of the species, and is wanting in others, is here represented by a strong longitudinal angle, which extends from the base of the crown to its apex, dividing the external face into two distinct planes. This character is most marked on the external incisor, where the planes are sub-equal, and concave. On the second the anterior plane is smaller, and on the first it is a good deal smaller. These incisors have a weak internal cingulum, but no external one.

Measurements.		M.
Length of ramus from P-M. IV inclusive		.257
" inferior true molars		.098
Diameters of M. I infer.	anteroposterior	.0275
	transverse	.020
Diameters of M. III infer.	anteroposterior	.036
	transverse	.029
Depth of ramus at M. III		.075
Diameters of M. II super.	anteroposterior	.0315
	transverse	.039
Diameters of crown of superior canine	longitudinal	.094
	anteroposterior	.022
	transverse	.034
Diameters of crown of I. iii	vertical	.022
	transverse	.024

The numerous characteristic marks, show that this species is one of the most distinct of the genus. It is also one of the largest, being second only to the *C. anax*.

CORYPHODON MARGINATUS, sp. nov.

This is one of the smaller species, having nearly the dimensions of the *C. molestus*. It is only represented by the superior canine, first inferior premolar, and last superior molar of one individual found together by Mr. Wortman. Their size, mineral condition and degree of wear, render it probable that all belong to one individual.

The superior molar is of the oval type, without posterior shoulder. The posterior crest is therefore straight, and parallel with the anterior crest. Its inner extremity does not display the least tendency to form a V, as is seen in *C. elephantopus*. Its exterior extremity is widely separated from the external prominence of the anterior crest (cingulum). The latter displays, at its inner extremity, the peculiarity of a deep fissure of the anterior side, which nearly divides the crest, and partially isolates the internal tubercle. Adjacent to the fissure its crest is tuberculate. The posterior upper cingulum descends from the inner cusp to the basal cingulum. The basal cingulum is well developed on the anterior and interior sides of the crown, and on the posterior as far as the base of the inner cusp of the posterior crest, where it gradually fades out. Enamel wrinkled.

The superior canine is remarkable for its small size. The posterior face is a little the widest, and its bounding edges are sharp, but not expanded. There are no prominent ridges of the enamel. The anterior face is moderately wide. The first inferior premolar presents no peculiarities.

Measurements.		M.
Diameters of M. III superior	anteroposterior	.028
	transverse	.038
	vertical	.019
Diameters of P-m. I inferior	anteroposterior	.015
	transverse	.009
Diameters of C. superior	anteroposterior	.014
	transverse posterior	.018

The superior molar is but little worn, and shows that the animal was just adult. The canine is more worn than the molar.

There are several characters which mark this species as distinct from those previously known. It is the only member of the genus which has a complete internal cingulum. The fissure of the anterior crest, if normal, is peculiar to this species. The superior canine is disproportionately small.

Besides the *Coryphodons* already mentioned, a number of more or less complete skeletons were obtained, some of which can be identified by comparison with those which are accompanied by teeth, and which are enumerated in the preceding pages.

METALOPHODON TESTIS, sp. nov.

The genus *Metalophodon* was described by me in 1872.* Since that time it has remained without further illustration of importance, as no good specimens of it have been obtained by any of my expeditions up to the present year. Thy material now at hand consists of the entire superior molar series of the right side, and the superior molars of the left side, in beautiful preservation. These display the characters on which the genus was proposed, *i. e.*, the conversion of the posterior external V of the second true molar into a transverse crest similar to that of the last true molar. It follows that the first true molar is the only one which exhibits this V. It also follows that in this genus the peculiarities of the dentition of *Coryphodontidæ* are carried further than in *Coryphodon*, where two molars display the V, and one the crest; or than in *Manteodon*, where all three have a V, and none the crest. The genera then stand in the order of evolution, *Manteodon*, *Coryphodon*, *Metalophodon*.

Char. specif.—The first superior premolar has lost its crown. The other premolars do not display any marked peculiarities. The internal cusps are well developed, and are most prominent posterior to the line of the apex of the exterior crest. They connect with the posterior cingulum by a broad ledge, but do not connect with the anterior cingulum. The two cingula nearly connect round the inner base of the crown on the third premolar.

The first true molar is well worn. The base of the posterior external V can be seen, and the anterior and posterior cingula. There is no internal cingulum. The second true molar is the largest of the teeth. It is subtriangular in outline, its external side forming with the posterior, a right angle. Its general character is much like that of the Coryphodontes, but it presents the remarkable exception which constitutes the character of the genus *Metalophodon*. The posterior crest does not include a V, but is straight, and consists of the same elements as the posterior crest of the third true molars, but differently proportioned. The part representing the anterior V is a cone, much shorter than the part corresponding to the posterior V. As there is a postero-exterior angle of the crown there is an oblique surface rising to this part of the crest, which represents the external face of the V. There is also a small tubercle at the angle, where a similar one is found in the corresponding tooth of *Ectacodon cinctus*. Altogether this tooth is like the posterior molar of *Coryphodon elephantopus*, with a more prominent postero-external angle added. The anterior and posterior basal cingula are well developed, the latter being strong interiorly to the point where it sends a branch upwards to the internal cusp. There is no internal cingulum.

The last superior molar is a transverse oval, more regular than usual in the species of *Coryphodon*, since the diameters of the internal and external portions are about equal. The characters of the posterior crest differ from

* Proceedings American Philos. Soc., 1872, p. 542.

those seen in the genus named in that the internal portion is much smaller than the external, having a small conic apex, distinct from that of the exterior portion. Its postero-external face is nearly vertical, and it diverges a little posterior to parallel with the anterior crest. The latter (the first cingulum) is elevated, and is widely separated externally from the posterior crest, to whose base it descends on the external extremity of the crown. The basal cingulum is present all round the crown except at the base of the posterior crest, and externally. It is narrow on the inner extremity of the crown. It sends upwards a strong branch to the apex of the internal cusp. The enamel of all the molars is strongly wrinkled, but is worn smooth wherever rubbed.

Measurements.		M.
Length of superior molar series		.179
" premolar series		.085
Diameters P-m. II	anteroposterior	.019
	transverse	.025
Diameters M. I	anteroposterior	.029
	transverse	.032
Diameters M. II	anteroposterior	.036
	transverse	.042
Diameters M. III	anteroposterior	.0285
	transverse	.041
	vertical	.015

The *Metalophodon testis* differs from the *M. armatus*, in the more triangular form of its penultimate superior molar. Its form is quite different from that of the last molar, while in *M. armatus*, the two teeth resemble each other closely. The species are of about the same size.

The individual from which the above description is taken is rather aged.

Dinocerata.

Bathyopsis fissidens Cope.

Bulletin U. S. Geolog. Survey, Terrs., Feb. 1881, 194.

A considerable part of the dentition of the mandible of this species was found in the Big-Horn bad lands. This includes an incisor tooth, which is quite characteristic, and renders it probable that the anterior parts of the jaws differ considerably from those of other *Uintatheriidæ*. The root is sub-round. The crown resembles a good deal that of the species of *Coryphodontidæ*. It is higher than wide and has a subacute apex. One edge of the crown is convex, and the other concave. The external face is concave in both directions, and has no ridges nor cingulum. The inner face is concave longitudinally and convex transversely. The convexity is median and has a longitudinal concavity on each side of it. No internal cingulum except a trace at the base of the concave edge. The edges are obtuse even when unworn, and the enamel is obsoletely rugulose.

Measurements of incisor.		M.
Diameters of crown	anteroposterior	.012
	transverse	.020
	vertical	.020
Diameters of root	anteroposterior	.012
	transverse	.014

This incisor is very different from the kind seen in *Loxolophodon*. Mr. Osborne has shown that genus to have these teeth with compressed two-lobed crowns, a type unknown elsewhere among *Mammalia*.*

PERISSODACTYLA.

In a paper on the "homologies and origin of the molar teeth of the Mammalia Educabilia," published in March, 1874,† I ventured the generalization that the primitive types of the Ungulata would be discovered to be characterized by the possession of five-toed plantigrade feet, and tubercular teeth. No Perissodactyle or Artiodactyle mammal was known at that time to possess such feet, nor was any Perissodactyle known to possess tubercular teeth. Shortly after advancing the above hypothesis, I discovered the foot structure of *Coryphodon*, which is five-toed and plantigrade, but the teeth are not of the tubercular type. For this and allied genera, I defined a new order, the *Amblypoda*. and I have published the confident anticipation that genera would be discovered which should possess tubercular (bunodont) teeth. This prediction has not yet been realized. I now, however, record a discovery, which goes far towards satisfying the generalization first mentioned, and indicates that the realization of the prophecy respecting the *Amblypoda*, is only a question of time.

In 1873,‖ I described from teeth alone, a genus under the name of *Phenacodus*, and although a good many specimens of the dentition have come into my possession since that date, I have never been able to assign the genus its true position in the mammalian class. The teeth resemble those of suilline Ungulates, but I have never had sufficient evidence to permit its reference to that group. Allied genera recently discovered by me, have been stated to have a hog-like dentition, but that their position could not be determined until the structure of the feet shall have been ascertained.§

In his recent explorations in the Wasatch Eocene of Wyoming, Mr. J. L. Wortman was fortunate enough to discover nearly entire skeletons of *Phenacodus primævus*, and *P. vortmani*, which present all the characters essential to a full determination of the place of *Phenacodus* in the system. The unexpected result is, that this genus must be referred to the order *Perissodactyla*, and that with its allies, it must form a special division of that order corresponding in the tubercular characters of its teeth with the

* A Memoir on *Loxolophodon* and *Uintatherium*. By H. Osborne.

† Journal of the Academy of Natural Sciences, Philadelphia.

‖ Palæontological Bulletin No. 17, Oct., 1873, p. 3; also, Report G. M. Wheeler, U. S. Engineers Expl. W. 100 Mer., iv, p. 174—1877.

§ Proceedings Amer. Philos. Society, 1881, p. 495.

bunodont or suilline division of the *Artiodactyla*. In this character, however, there is a closer gradation than in the case of the *Artiodactyla*, and it would scarcely be necessary to create such a group on that character alone. But the genus differs further from the *Perissodactyla* and approaches the *Proboscidia*, in the fact that the astragalus articulates with the navicular only, and by a universally convex surface, as in the Carnivora.

The astragalus resembles that of the latter order very closely, and differs from that of *Hyracotherium* and the nearest forms among the *Perissodactyla*. *Phenacodus* has moreover five well developed toes on all the feet, and was probably not entirely plantigrade. The cast of the brain case shows that the cerebral hemispheres were quite small and nearly smooth, and that the very large cerebellum and olfactory lobes were entirely uncovered by them. The bones of the two carpal rows alternate with each other, and there is a large third trochanter of the femur. The cervical vertebræ are opisthocœlous.

This group is then the ancestral type of the known *Perissodactyla*, that is of the horses, tapirs and rhinoceroses, and of the numerous extinct forms. Its systematic position may be schematically represented as follows:

Order PERISSODACTYLA; ungulate; digits of unequal lengths; carpal bones alternating; a postglenoid process. Astragalus with proximal trochlea, and without distal double ginglymus.

Suborder *Diplarthra;* astragalus distally plane or concave in one direction, and uniting with both navicular and cuboid bones; a third trochanter of the femur. The known families belong here.

Suborder *Condylarthra;* astragalus convex in all directions distally, only uniting with navicular bone; a third trochanter of femur.

Family *Phenacodontidæ*. Molar teeth tubercular; the premolar teeth different from the molars; five digits on all the feet.

Genera; *Phenacodus* Cope, and very probably *Catathlæus*, *Anacodon* and *Protogonia* Cope, and perhaps also *Anisonchus* Cope. These genera include fifteen species, all from the lower Eocene beds. I gave a synopsis of their differential dental characters in the Proceedings of the Philosophical Society, 1881, p. 487, where I included also the genus *Mioclænus*. I omit the latter from the family at present, as I believe it to be Artiodactyle.

PHENACODUS PRIMÆVUS Cope.

Parts of a dozen individuals of this species were obtained, and one almost entire skeleton in a block of soft sandstone. This includes nearly all parts of the four extremities, as well as the skull, from which but small portions are wanting.

Species of this genus, so far as determinable from the dentition, are numerously represented in Mr. Wortman's collection. About fifty individuals are referable to eight species. These present a great range in size, and some diversities of structure. They may be distinguished as follows:

I. Last inferior molar with oval outline; heel small; anterior inner cusp simple.

Size medium; length of true molars .025; depth of ramus at M. II, .018. *P. apternus.*

II. Last inferior molar wedge-shaped, with heel prominent; anterior inner cusp simple.

Large; true molars .041; P-m. IV .014; depth of ramus at M. II, .027. *P. primævus.*

Medium; true molars .027; depth at M. II .017; last molar smaller..... *P. vortmani.*

Smaller; true molars .022; depth at M. II .013; last molar elongate;.. *P. macropternus.*

Smaller; last four molars .027; P-m. IV .007; depth at M. II .013; last molar with short heel.....*P. brachypternus.*

Smallest; true molars .017; depth at M. II .012; heel long; cusps elevated.....*P. zuniensis.*

III. Last inferior molar wedge-shaped, with prominent heel; anterior inner cusp double;

Least; last inferior molar .006; heel narrow; true molars (superior) .016. *P. laticuneus.*

Two other species have been described, the *P. sulcatus*, and *P. omnivorus* Cope. The former I suspect belongs to another genus. I am not now sure of the distinctness of the latter from *P. primævus.*

PHENACODUS HEMICONUS, sp. nov.

Represented by the posterior two superior molars of an individual intermediate in size between the *P. primævus* and *P. puercensis.* The posterior molar is peculiar in the very rudimental character of the posterior internal lobe, which is reduced to a mere wart on the cingulum. The posterior external tubercle is also rudimental, not exceeding the posterior inner in dimensions. The anterior tubercles, including the intermediate, are well developed, the internal exceeding the external. The cingulum is wide and crenate, and is only wanting on the external base of the crown. The penultimate molar does not differ so much from that of *P. primævus*, but the two internal cones are not so deeply separated at their base. The tubercles are all but little worn, and are conical in form, the external flattened on the external faces. Enamel wrinkled.

Measurements.		M.
Diameters of M. II	anteroposterior	.009
	transverse	.012
Diameters of M. III	anteroposterior	.010
	transverse	.013

The size of this species precludes the possibility of its identity with any of the other species described here.

PHENACODUS WORTMANI Cope. Bulletin U. S. Geol. Surv. Terrs. vi, 1881, p. 199. *Hyracotherium vortmani*, American Naturalist, 1880, p. 747.

PROC. AMER. PHILOS. SOC. XX. 111. W. PRINTED MARCH 16, 1882.

Phenacodus puercensis Cope. Proceeds. Amer. Philos. Soc. 1881, p. 492.

An abundant species, represented by twelve mandibular rami in the collection, and by a nearly entire skeleton with perfect skull.

PHENACODUS APTERNUS, sp. nov.

Three rami, each of which supports the true molar teeth, indicate this species. The oval form of the posterior molar is due to the shortness of the heel, and the large size of the internal median tubercle, which projects inwards, giving a convex outline to the interior side of the crown. The external tubercles of all the true molars wear into crescents; and the anterior inner is more robust than the posterior inner.

PHENACODUS MACROPTERNUS, sp. nov.

This species is apparently rare, being represented by only one mandibular ramus, which supports the posterior three molars, and a possible second ramus with molars iv and v. The first and second true molars are much like those of *P. vortmani*, but the third is relatively larger, and has an especially elongate heel. In *P. vortmani* the last molar is constricted, and narrower than the penultimate. In *P. macropternus* there is a weak external, and no internal cingulum. The tubercles of the last two molars are quite regularly conical, while the external pair of the first molar, wear into crescents. Smaller than the *P. vortmani*.

PHENACODUS BRACHYPTERNUS, sp. nov.

Three mandibular rami are the only specimens of this species found by Mr. Wortman in the Big-Horn region. They all display the fourth premolar, which has the characters of this genus, as distinguished from *Mioclænus*. The species is materially smaller than the *P. vortmani*, and its last inferior molar is intermediate between those of the latter and the *P. apternus*, in form. Both the internal and external intermediate tubercles are very full, and give the tooth posterior width. The posterior or fifth tubercle is large, and gives the posterior outline of the crown a trifoliate form. The posterior median tubercles of the M. II and I, are well marked. The molars gradually increase in size forwards, and the fourth premolar is longer than any of them, and rather narrow. The heel of the P-m. III is short and wide. On the true molars a weak external cingulum. Enamel slightly wrinkled.

PHENACODUS ZUNIENSIS Cope. Proceeds. Amer. Philosoph. Society, 1881, p. 462.

Mr. Wortman obtained eleven mandibular rami of this species, in only one of which are the premolars preserved. Excepting the *P. laticuneus*, this is the smallest species of the genus. The molars have much the appearance of those of the Mesodont genus *Hyopsodus*, but may be distinguished by the size of the posterior median tubercle. The second true molar is the widest tooth, and the last molar is rather elongate, and its cusps are not exactly opposite to each other. The cusps of the molars

are more elevated than in the other species, and those of the external side all have a distinctly crescentic section. The anterior inner cusp is narrow and simple. There is no cingulum of any kind.

This species was originally described from New Mexican specimens.

PHENACODUS LATICUNEUS, sp. nov.

This is the least species, and is represented by six superior molars and the last inferior molar in a fragment of the lower jaw. The latter tooth exhibits peculiar characters already mentioned. The superior molars differ from those known to belong to the *P. primævus* and *P. puercensis* in having a vertical fissure of the inner side which separates the bases of the two internal tubercles. This gives them some resemblance to the superior molars of the species of *Anisonchus*, but the important difference remains in the separation of the anterior inner tubercle from the intermediate tubercles. The three are confluent into a V in the genus last mentioned.

The external cusps of the superior molars are rather acute, and lenticular in section, their external sides forming a convex rib. There is no rib between the external sides. There is a strong anterior cingulum, which terminates externally in a low angular cusp. There is no cingulum on any other part of the crown. The second, third and fourth premolars have two external cusps, and much resemble the corresponding teeth in *Hyracotherium*. The second is longer than wide, and has an internal ledge; the third is as wide as long and has a wide internal ledge; the fourth is wider than long and has an internal, and two intermediate cusps, and an anterior and posterior cingulum. They all have a weak external cingulum, of which a trace exists in the true molars.

The last inferior molar has a double anterior inner cusp as in some *Mesodonta*, and the external anterior cusp is robust. All the cusps are conical and with round section, and their bases are close together. The outline of the base of the crown is almost an isosceles triangle with rather wide base in front.

Measurements.	M.
Length of last six superior molars	.0350
" true molars	.0160
Diameters of M. II anteroposterior	.0055
Diameters of M. II transverse	.0080
Long diameter base of P-m. II	.0050
Diameters P-m. III anteroposterior	.0060
Diameters P-m. III transverse	.0060

ANACODON URSIDENS, gen. et sp. nov.

Char. gen. Known only from mandibles supporting molar teeth. Probably family *Phenacodontidæ*. Last inferior molar with heel. Crowns of molars without distinct cusps, but with a superior surface consisting of two low transverse ridges separated by a shallow valley. Unworn grinding surface with shallow wrinkles. Perhaps only three premolars.

Char. specif. Broken mandibular rami of two individuals constitute the basis of my knowledge of this species. It is of the size of the *Phenacodus primævus*. The last inferior molar is wedge-shaped with the very obtuse apex posterior. It displays two slight transverse elevations anteriorly which represent the usual cusps. Grinding surface generally nearly flat. The posterior half of the crown of the penultimate molar is flat, and is separated from the anterior half by a transverse groove. Its surface is marked by shallow branching grooves.

The molar preceding this one in the broken specimen is probably the first. It is possible from its slightly worn condition that it is the fourth premolar, but the form is that of a true molar. The surface of the crown is marked by shallow grooves not very closely placed. The three premolar teeth in advance of this tooth are broken off. Their bases are narrow. There are no basal cingula on the molars.

Measurements.	M.
Length of posterior true molars	.033
Diameters of M. III { anteroposterior	.015
Diameters of M. III { transverse	.010
Diameters of M. ? I { anteroposterior	.015
Diameters of M. ? I { transverse	.011
Depth of ramus at M. II	.030

The characters of the teeth of this species are something like that of some of the *Palæochœri* of the Miocene, and resemble more those seen in some of the bears.

OLIGOTOMUS OSBORNIANUS, sp. nov.

Char. gen. Dental formula; I. ?, C. ?, P-m. ? $\frac{4}{4}$; M. $\frac{3}{3}$. External faces of external lobes of superior molars separated by a ridge; anterior external cusp of cingulum little developed. Premolars of superior series different from true molars, with only one internal lobe. Fourth inferior premolar similar to the true molars. Cusps of inferior molars connected by diagonal ridges forming Vs. A diastema in front of the second premolar.

This genus is a good deal like *Lambdotherium*, so far as known. Its superior molars are much like those of *Aceœssus*, and their intermediate and internal tubercles are those of *Hyracotherium*.

The two or three species known to me are of small size.

Char. spec. The true molars of both maxillary bones, with the fourth premolar of one side are preserved more or less perfectly, with four inferior molars on two fragments of the lower jaw.

The external tubercles of the superior molars are nearly erect, and have a lenticular section. The rib which separates their external faces is prominent, and terminates in a free apex. The base of each face is marked by a strong cingulum, but the posterior one is very short. There is a strong anterior basal cingulum, but no posterior or internal one. The anterior inner tubercle is larger than the posterior. The intermediate tubercles are

sub-round, and are anterior to the transverse line of the interior ones. They do not join the latter excepting after very considerable wear. The external anterior cingular cusp is rather more prominent on the first than on the second true molar. The fourth superior premolar has a well marked external anterior cingular cusp, which is, however, low; and there is no ridge dividing the external faces of the external cusps. The single inner cusp is connected with the two external by two ridges, which diverge as they extend outwards. The anterior supports a tubercle close within the anterior external. There are strong anterior and posterior basal cingula and weak external and internal ones.

The third inferior premolar has a compressed ridge on the heel. The fourth premolar is like a true molar, with the anterior inner cusp well developed and elevated, and connected with the anterior and posterior external by oblique ridges. The inner posterior cusp is less conic in form than in the true molars, and the entire crown is somewhat contracted anteriorly. The true molars are characterized by the presence of a small median tubercle on the posterior border. There is a low external basal cingulum, which is wanting opposite the posterior cusp. Enamel generally smooth.

Measurements.	M.
Length of superior true molar series	.0210
Diameters of superior M. II { anteroposterior	.0080
Diameters of superior M. II { transverse	.0097
Diameters of P-m. IV { anteroposterior	.0085
Diameters of P-m. IV { transverse	.0085
Length from inferior P-m. III to M. II inclusive	.0290
Diameters of P-m. IV { anteroposterior	.0080
Diameters of P-m. IV { transverse	.0050
Diameters of inferior M. II { anteroposterior	.0075
Diameters of inferior M. II { transverse	.0060
Depth of ramus between P-m. III and P-m. IV	.0150

As compared with the *O. cinctus*,* this species differs in its superior dimensions. The anterior inner cusp of the inferior molars is probably single, though the slightly worn condition of those teeth renders this point a little uncertain. In *O. cinctus* some of them at least are double.

This species was, to judge from the size of its teeth, about the size of a red-fox. The specimens of it above described were found by Mr. J. L. Wortman in the bad lands of the Big-Horn river, Wyoming. It is dedicated to my friend, Henry L. Osborne, of Princeton College, New Jersey.

SYSTEMODON TAPIRINUS Cope. American Naturalist, 1881, p. 1018.

Hyracotherium tapirinum Cope. Systematic Catalogue of the Eocene Vertebrata of New Mexico, 1875, p. 20. Report U. S. Geol. Surv. W. of 100th mer. Capt. G. M. Wheeler, iv. ii. p. 263. Pl. lxvi. figs. 12–16.

This species was abundant in Wyoming during the Wasatch epoch, jaws and teeth of more than twenty individuals having been brought by

* Annual Rept. U. S. Geol. Survey Terrs. 1872, p. 607.

Mr. Wortman from the Big-Horn. From these I learn that the dental system is different from that characterizing the species of *Hyracotherium*. There is no diastema posterior to the superior canine, while in the latter genus there are two. Anterior to the canine there is a considerable one in the *Hyracotherium*. This part is not preserved in any of the specimens of *S. tapirinum*. The characters mentioned have induced me to separate the latter as type of a distinct genus, *Systemodon*. An examination of the figures and descriptions given by Dr. Lemoine of his *Pachynolophus gaudryi* found by him in the neighborhood of Reims, shows that it belongs to the genus *Hyracotherium*. It is therefore distinct from either of the species of *Systemodon*, and is to be compared with the *H. craspedotum* of the Wind River country, with which it agrees in size.

SYSTEMODON SEMIHIANS, sp. nov.

This species was also abundant in the Big-Horn region, jaws and teeth of sixteen individuals having been obtained. Its dimensions are a little smaller than those of the *S. tapirinus*, especially as to the premolar teeth. There is also a short postcanine diastema, which is not seen in the *S. tapirinus*.

The proportions of the maxillary series are represented by a left maxillary and premaxillary bone, with all the teeth in place, but the crowns lost from the first premolar anteriorly. The crowns of the true molars are somewhat worn, so I confine the description of these to the premolars. The third and fourth have considerable transverse extent, the latter being wider than long. The second has scarcely any internal tubercle, but only a low postero-internal heel. The internal tubercle of this tooth is large in *S. tapirinus*. The crown has two cusps, the posterior lower. The last two premolars have two external cusps close together. They have also an anterior external cingular lobe, as in the true molars. There is a posterior external basal lobe in the third premolar, but none or a rudiment on the fourth. No internal cingulum on the premolars. The superior true molars, although worn, show a prominent anterior external basal lobe, and no complete internal cingulum The base of the crown of the first premolar is narrow antero-posteriorly, and it has two roots as in *S. tapirinus*. It is in close contact with the second premolar, and is separated from the base of the canine by a space a little less than its own anteroposterior diameter, and less than the diameter of the canine. The base of the crown of the latter shows that it is not a large tooth, and has a wide lenticular section. The base of the external incisor is rather large, and is compressed.

Measurements of superior teeth.	M.
Total length of superior series	.0720
" " " molar "	.0310
" " " premolar "	.0250
Diameters base of canine { anteroposterior	.0055
Diameters base of canine { transverse	.0040

Measurements of superior teeth.		M.
Length of base of P-m. I		.0040
Diameters P-m. III	anteroposterior	.0070
	transverse	.0078
Diameters P-m. IV	anteroposterior	.0070
	transverse	.0090
Diameters M. III	anteroposterior	.0100
	transverse	.0125

Some superior molars in better condition than those last described, exhibit the following characters. The intermediate tubercles are fused with the internal, forming a continuous cross crest, but their apices are distinguishable. The external cusps are subconical and are well separated. The anterior and posterior cingula are strong, the external is weaker, and it is wanting from the posterior part of the internal base of the crown.

A portion of a mandibular ramus, supporting six molars, presents the following characters. The teeth are a little smaller than those of *S. tapirinus*, the reduction being especially visible in the premolars. The cones of the crowns are more distinctly separated by notches than in that species, and are quite distinctly conic. The anterior ledge of the true molars is distinct, and there is a median posterior tubercle of the first two, which is represented by the wide crenate-edged heel of the third true molar. The anterior-internal cusps of the last two molars is double or bilobed; that of the first is last. The anterior cones of the fourth premolar are subequal, and the posterior external cone is elevated. There is a trace of the posterior internal. There is also an anterior ledge. The heel of the third premolar rises to a median blade and posterior cusp. The anterior cusp is elevated and compressed, and supports a small internal lateral cusp. The base of the crown of the third premolar is elongate. All the teeth are rather compressed, and there is only a trace of an external cingulum.

The ramus is compressed and moderately deep. The dental foramen is large, and its superior border is on a level with the posterior base of the crown of the third true molar. Its inferior base is in line with the base of the crown of the second true molar.

Measurements of mandible.		M.
Length of last six molars		.0530
" true molars		.0310
Diameters third premolar	anteroposterior	.0065
	transverse	.0040
	vertical	.0052
Diameters second true molar	anteroposterior	.0092
	transverse	.0060
	vertical	.0062
Diameters third true molars	anteroposterior	.0120
	transverse	.0060
Depth of ramus at P-m. III		.0170
Depth of ramus at front of M. III		.0220

The nearest ally of this species outside of the genus *Systemodon* is probably the *Hyracotherium craspedotum* Cope. This species was brought from the Wind River bad lands, and does not occur in the Big-Horn collection. It is about the size of the *S. semihians*, but is a true *Hyracotherium*, with a diastema behind the first premolar. The strong cingulum which characterizes it is not found in the *S. semihians*, and the inferior molars are wider and more robust.

HYRACOTHERIUM CRASPEDOTUM Cope.

Bulletin U. S. Geol. Survey, Terrs., 1881, p. 199. American Naturalist, 1880, 747.

The dentition of this species is in its dimensions and proportions intermediate between the two species of *Systemodon*. Its three premolars equal four of those of the *S. semihians*, while the molars of the two species are about equal.

A specimen having the proportions of the *H. craspedotum* was found by Mr. Wortman on the Big-Horn, but unfortunately it does not exhibit the characteristic cingula of the two dental series. The second superior premolar, like that of *Systemodon semihians* has no internal tubercle. It is not certain whether there is any diastema posterior to the first superior premolar. I therefore cannot yet ascertain whether this specimen represents an undescribed species of *Systemodon* or *Hyracotherium*, or a strong variety of the *H. craspedotum*. The accompanying inferior true molars are intermediate in size between those of the latter species and the *H. vasacciense*.

HYRACOTHERIUM VASACCIENSE Cope.

This species differs from the *H. venticolum* in its deep mandibular ramus. A single specimen from the Big-Horn presents the same proportions. The posterior inferior molar is rather short.

HYRACOTHERIUM VENTICOLUM Cope.

Bulletin U. S. Geol. Survey, Terrs., 1881, 198.

Fifteen individuals of this species are included in the collections.

HYRACOTHERIUM ANGUSTIDENS Cope.

This was a very abundant species. Mr. Wortman's collection contains jaws and teeth of twenty individuals sufficiently well preserved for identification, and a large number of other pieces of jaws, etc., which may be reasonably inferred to belong here.

In my report on the Wind River collection*, I noticed three varieties of this species, which differ in the depths of the ramus at the line of junction of the fourth and fifth molars. The numbers are 12, 14, and 15.5 mm. respectively. The lengths of the first true molar also vary from 7 to 6.5 and 7.5 mm. respectively. The last true molar measures in all 10.0 mm. The majority of the Big-Horn specimens agree with the second variety, but two others occur, one a little smaller, and the other a little larger than the average. The former measures; length of last molar .0090; of

* Bulletin U. S. Geol. Survey Terrs. vi, 1881, p. 198.

first molar .0067; depth of ramus at M. I, .0120. The dimensions of the larger variety are: length of M. iii, .110; of M. i, .0067; depth ramus .0165. The New Mexican forms originally described, exhibit combinations of several of these measurements.

PACHYNOLOPHUS VENTORUM Cope.

Bulletin U. S. Geol. Surv. Terrs., 1881, p. 197. American Naturalist, 1880, p. 747.

One mandibular ramus.

PACHYNOLOPHUS POSTICUS, sp. nov.

Both rami of a mandible represent this large species. They are somewhat injured, and the crowns of five of the molars only can be distinctly seen. The latter display the characters seen in the *P. ventorum* and other species of the genus. The transverse crests are well characterized, and the valley between them uninterrupted. They are closed at the inner extremity by a low ridge nearly at right-angles with the cross crest posterior to them, as in the species of *Rhinocerus*. The anterior of these bounds an anterior ledge, which is quite large on the last true molar. The latter has a rather narrow, but prominent heel, which rises posteriorly. The fourth premolar has an anterior ledge, and wide heel with a diagonal crest which is median in front. The third premolar is similar, but smaller. The only cingulum is seen on the anterior part of the external side of all the true molars.

Measurements.	M.
Length of crowns of posterior six molars	.0700
" " true molars	.0440
Diameters P-m. iv { anteroposterior	.0095
Diameters P-m. iv { transverse	.0070
Diameters M. ii { anteroposterior	.0130
Diameters M. ii { transverse	.0095
Diameters M. iii { anteroposterior	.0180
Diameters M. iii { transverse anteriorly	.0092
Depth ramus at P-m. ii	.0280
" " M. ii	.0310

ARTIODACTYLA.

MIOCLÆNUS BRACHYSTOMUS, sp. nov.

Char. gen. The typical specimen of this species is represented by all the molar dentition of both jaws excepting the anterior three superior premolars. It also includes pelvis, femur, the distal parts of the tibia and fibula, the entire tarsus and the proximal portion of the metatarsus.

The dental characters conform precisely to those of the other species of *Mioclænus*. There is but one internal cusp of the superior true molars, and the intermediate tubercles are present. The fourth premolar has one external and one internal lobe. The inferior premolars have simple crowns without interior cusps or tubercles.

The characters of the tarsus are of much interest, and demonstrate that *Mioclænus* is the oldest type of artiodactyle yet discovered, and that it is not altogether primitive in some of its characters. Members of this order have been found by Cuvier in the upper Eocene (*Dichobune, Anoplotherium*, etc.), but none have been determined as yet from the Suessonian of America. A species represented by teeth from the Siderolithic beds of Switzerland have been referred to *Dichobune* (*C. campichii* Pict.); but dental characters alone are not sufficient to distinguish that genus from *Phenacodontidæ**. Dr. Lemoine found astragali of a small Artiodactyle in the Suessonian of Reims, and has referred them to his supposed Suilline *Lophiochærus peroni*. I have reported an astragalus from the Wind River formation of Wyoming Territory, which is almost exactly similar to those found by Lemoine. The specimen now described, enables me to characterize with some degree of completeness this interesting form, which precedes in time all the known American *Artiodactyla*.

The characters of the tarsus are typically those of the order *Artiodactyla*. The astragalus exhibits a distal trochlea which is continuous with the sustentacular facet, and which articulates with both cuboid and navicular. The distal portion of the fibula is free from the tibia, and its shaft becomes very slender. It is possible that a more perfect specimen would display it as continuous. Its distal extremity articulates with the ascending tuberosity of the calcaneum. The cuboid facet of the latter is narrow. The cuboid and navicular bones are distinct from each other and from the cuneiforms. The mesocuneiform is shorter than the ectocuneiform, and *is coössified with it*. There are probably four metatarsals. The median pair are distinct, but appressed, their section together, sub-circular. The lateral metatarsals are slender, the external one is wanting, but its facet on the cuboid bone is very small.

These characters are in general similar to those of the genus *Dichobune*, but Cuvier† does not state whether the cuneiforms are coössified in that genus or not. They are united in Anoplotherium.‡ *Mioclænus* differs from *Dichobune* in the presence of but one internal tubercle of the superior molars, and in the single external tubercle of the superior premolars. Both genera are referable to a family to be distinguished from the *Anoplotheriidæ* by the presence of the external digits. This has been already named by Gill the *Dichobunidæ*.

Char. specif. The bones are about two thirds the size of those of the Javan musk-deer (*Tragulus javanicus*). The transverse extent of the superior true molars is greater than the anteroposterior. The composition of the last molar is like that of the others. The external tubercles are lenticular in section and the emargination which separates them is apparent on the external face of the crown. The intermediate tubercles are small, and are entirely distinct from the large external tubercle. There

* See American Naturalist, 1881, December.

† Ossemens Fossiles, v, p. 183.

‡ Gaudry Enchainements d. Regne Animal, p. 147.

is a distinct cingulum which is only wanting from the inner base of the crown. The fourth superior premolar has a trilobate outline of the base of the crown, the base of the inner lobe being contracted where it joins the external part of the crown. The internal tubercle is conic, with a prolongation outwards and forwards. Intermediate tubercle not distinct. External, anterior, and posterior cingula.

In the inferior true molars the external tubercles wear into crescents. The crowns increase in size posteriorly, which is the reverse of the order of enlargement in some of the other species of the genus. The fifth tubercle of the last molar is rather small, but is well distinguished from the other cusps. The internal median cusp is small, the external median. large. The premolars are not so much larger than the true molars in this as in the typical species of the genus. The second and third are more elongate on the base than the fourth. The latter is also less compressed than those that precede it. It has a short wide heel, and a small anterior basal tubercle. In the second and third premolars the posterior edge of the principal cusp is sharp, and descends gradually to the posterior base of the crown. Both have small acute anterior basal tubercles. The first inferior premolar is one-rooted, and has a simple crown directed somewhat forwards. It is separated from the second by a short space. The teeth anterior to this point are lost.

Measurements.		M.
Length posterior four superior molars		.0182
Diameters P-m. IV	anteroposterior	.0040
	transverse	.0042
Diameters M. II	anteroposterior	.0043
	transverse	.0060
Diameters M. III	anteroposterior	.0040
	transverse	.0060
Length of inferior molars		.0330
" "	premolars	.0192
" "	P-m. III	.0055
" "	P-m. IV	.0045
Diameters M. I.	anteroposterior	.0040
	transverse	.0033
Diameters M. III	anteroposterior	.0052
	transverse	.0040
Depth of ramus at P-m. I		.0047
" "	M. II	.0090
Length of astragalus		.0102
Width of trochlea behind		.0048
Diameters of cuboid	length	.0070
	width of middle	.0040

MIOCLÆNUS ETSAGICUS, sp. nov.

This, the largest species of the genus, is represented by the two rami of

a mandible of an adult animal in good preservation. In their robust character the premolar teeth resemble those of the *M. turgidus*, but are not relatively so large, nor is the last true molar relatively so small, as in that species. The heel of the third premolar is obsolete, and that of the fourth is a wide cingulum. Neither exhibit an anterior basal tubercle, and in both the principal cusp is stout. The true molars widen posteriorly to the anterior part of the last molar. The latter contracts rapidly to a narrow heel. The tubercles are all subconic, and the median ones of the last molar are small. There are no cingula, and the enamel is smooth.

The ramus is not robust, and is of moderate depth. Its inferior border rises below the middle of the last molar tooth, and posteriorly. There is a "mental" foramen below the contact of the fourth premolar and first true molar.

Measurements.	M.
Length of bases of six posterior molars	.047
" " three premolars	.024
" " P-m. II	.009
" " P-m. IV	.008
" " P-m. IV	.005
Diameters basis of M. II { anteroposterior	.0075
Diameters basis of M. II { transverse	.0070
Diameter basis M. III { anteroposterior	.0084
Diameter basis M. III { transverse	.0070
Depth of ramus at P-m. II	.0080
" " M. II	.0140

This species is named from the Crow Indian name of the Big-Horn river, *Etsagie*.

Concluding Remarks.

The paleontologist who has examined the preceeding list, will readily perceive that it represents fully the Wasatch fauna, with little admixture of earlier or later forms. The only genus which belongs to the Bridger or middle Eocene, which occurs in the Big-Horn basin, is *Pappichthys*. The characteristic Bridger genera *Hyrachyus*, *Palæosyops*, *Uintatherium*, and the *Tillodonta*, are absent, and their place is taken by *Phenacodus*, *Hyracotherium*, *Coryphodon* and *Tæniodonta*, as in New Mexico. Several genera are, as elsewhere, common to the two horizons, and two species cannot be distinguished in the parts preserved. Such as *Hyopsodus paulus* and *H. vicarius*. A closer comparison may be made with the Wind-River group, on which I published a report in the Bulletin of the U. S. Geological Survey of the Territories.* The following genera found in that formation have not been obtained from the Big-Horn. *Protopsalis*, *Lambdotherium*, *Palæosyops*, *Hyrachyus*.† Genera of the Big-Horn not obtained from the Wind-River: *Cynodontomys*, *Anaptomorphus*; *Mesonyx*,

*1881, Feb. p. 201.

† Since making my report on the Wind-River fauna, I have found the anterior part of the lower jaw of a species of this genus.

Deltatherium, Oxyæna; Manteodon, Ectacodon, Metalophodon; Anacodon, Oligotomus, Systemodon; Mioclænus. Three of these genera have been found in the Bridger, and five have been obtained in the lower Eocene of New Mexico. Five of the genera are new to science.

An especial feature of the Big-Horn collection, as distinguishing it from those brought from other regions of the Wasatch formation, is the presence of numerous species of *Phenacodus*, and of new and rare species and genera of *Coryphodontidæ*.

II. The Fauna of the Catathlæus Beds or Lowest Eocene of New Mexico.

A number of new species and genera from this horizon were described in my Paleontological Bulletin No. 33. The present paper adds a few to this list. Up to the present time no species of *Coryphodon*, and but few specimens of *Hyracotherium* have been discovered in this formation, thus exhibiting a marked contrast to the Wasatch beds. The predominant genus is *Catathlæus*, which is represented by one very abundant species. The genera of *Creodonta* are mostly distinct from those of the Wasatch. The Diplarthrous Perissodactyla, so numerous in the Wasatch, are rare here. The genus which is well represented in both formations, is *Phenacodus;* and *Mioclænus* occurs in both. *Mesodonta* are much less numerous than in the Wasatch, and *Amblypoda* have not yet certainly been found.

This is the only Tertiary formation where the Laramie genus *Champsosaurus* occurs. It is represented by three species.

Psittacotherium multifragum Cope.

American Naturalist, 1882, p. 156, Jan. 25th.

An interesting new form of this sub-order has been found in the *Catathlæus* beds (probably the Puerco formation) of New Mexico. It differs widely from the two genera hitherto known, *Anchippodus* and *Tillotherium*. Owing to the absence of the superior dental series, it is not possible to be sure which is the canine. The inferior dental formula may be therefore written, I. 2; C. 1; P-m. 3; M. 3; or I. 3; C. 0; P-m. 3; M. 3; or I. 3; C. 1; P-m. 2; M. 3. The first and second incisors are large and rodent-like, growing from persistent pulps; the second are the larger. The third, or canines, are small and probably not gliriform. There is no diastema. The first premolar (or canine) has a compressed crown with two cusps placed transversely to the jaw axis, and has a complete enamel sheath, and probably two roots. The succeeding tooth is also transverse, and is two-rooted, judging from the alveolus. The first and second true molars are rooted, and the crown consists of two transverse separated crests, each partially divided into two tubercles. On wearing, the grinding surface of each assumes the form of a letter B with the convexities anterior. The last inferior molar is injured. The rami are short, and the symphysis deep and recurved.

Specific characters. The base of the coronoid process is opposite the junction of the second and third true molars. The ramus is deep and mod-

erately stout. The enamel of the first incisor does not extend below the alveolar border, at the internal and external faces, and does not reach it at the sides. It has a few wrinkles on the anterior face. The anterior enamel face of the second incisor is thrown into shallow longitudinal grooves with more or less numerous irregularities from the low dividing ridges. There is a deeper groove on each side of the tooth, and there are about a dozen ridges between these on the anterior face. Both cusps of the first premolar are conic, and the external is the larger. The second true molar is a little smaller than the first. The enamel of the premolars and molars is smooth, and there are no cingula.

Probable length of dental series, .0750; diameters of I. 1: anteroposterior, .0120, transverse, .0066; diameters I. 2: anteroposterior, .0160, transverse, .0115; diameters P-m. 1: anteroposterior, .0072; transverse, .0130; diameters of M. ii. anteroposterior, .0090, transverse, .0090. Length of true molars, .0038; depth of ramus at M. ii, .0360.

The short deep jaws of this animal must have given it a very peculiar appearance, not unlike that of a parrot in outline.

PSITTACOTHERIUM ASPASIÆ, sp. nov.

Represented by two mandibular rami of two individuals, one adult, the other nearly so, but with the last inferior molar not fully protruded. The latter specimen must be used for description, as it presents two molar teeth, while the other specimen has lost them.

The most obvious difference from the *P. multifragum* is its inferior size, which can be readily perceived from the measurements given. The posterior crest of the molars appears to have less transverse extent than in the larger species. This crest in the last inferior molar has a curved crenate edge, with a small conic tubercle at its external extremity. The anterior crest consists of two conic tubercles, whose apices converge, but whose bases are closely appressed, and only distinguished by a superficial fissure. The valley between the crests is uninterrupted. The preceding molar is larger, and its posterior crest is like that of the lost molar. The apex of the anterior crest is broken off.

The ramus deepens rapidly forwards, and contains the enormous alveolus for the incisors. The coronoid process leaves the alveolar border at the line separating the last two molars, or, in the smaller specimen, a little anterior to this point, and is quite prominent. The masseteric fossa is well marked, but shallows gradually anteriorly and inferiorly.

Measurements.

	M.
No. 1.	
Depth of ramus at penultimate molar	.027
Width of last molar anteriorly	.008
Length of crown of do	.009
No. 2.	
Depth of ramus of penultimate molar	.029
" " at P-m. ii.	.043
Length of five consecutive alveoli	.047

From the Puerco bed of N. W. New Mexico.

TRIISODON HEILPRINIANUS, sp. nov.

This species may be readily recognized as smaller than the *T. quivirensis*, and as having the anterior inner cusp of the inferior true molar of larger proportions than in the corresponding teeth of the latter species. It is only represented in my collection by a portion of a lower jaw, which supports only one well preserved molar. As the fourth premolar is not present, it is not positively ascertained that the species does not belong to *Ictops*.

The anterior cusp is very low, and is nearer the inside than the middle of the anterior border. The principal anterior cusps are opposite, and the external is a little the larger. The heel is larger than the basis of the anterior cusps, and has convex borders. Its internal border supports three tubercles, and the external border rises into a cutting lobe with lenticular section. Enamel smooth. No cingula, but the external base is injured.

Measurements.			M.
Diameters of inferior molar	vertical	of cusps	.0070
		of heel	.0052
	anteroposterior		.0110
	transverse		.0065

Puerco beds of New Mexico.

Dedicated to my friend, Professer Angelo Heilprin, of Philadelphia.

SARCOTHRAUSTES ANTIQUUS, gen. et sp. nov.

Char. gen. We have in evidence of the characters of this genus, the last two superior molars, the last one lacking the crown; and parts of both mandibular rami, which exhibit teeth as far posteriorly as the first true molar inclusive; all belonging to one individual. A part of a skeleton of a second individual, which includes a fragment of lower jaw, belongs probably to this species.

Sarcothraustes resembles both *Amblyctonus* and *Mesonyx*, but it is probably to the latter genus that it is allied. The last superior molar is transverse, much as in *Oxyæna*. The crown of the penultimate is subtriangular and transverse. It has two external subconic cusps and a single internal lobe, whose section on wearing is a V, each branch of the face extending to the base of the corresponding external tubercle. There are three small inferior incisors, and a large canine. There are probably only three inferior premolars, the first one-rooted. The crown of the second has no heel. The crown of the third has a short wide heel. The crown of the first true molar consists of an anterior elevated cone and a posterior heel. The latter is wide, having a posterior transverse, as well as a longitudinal median keel. The fragments of the supposed second individual include two large glenoid cavities with strong preglenoid crests, as in *Mesonyx*.

As compared with *Mesonyx*, this genus differs in the V-shaped crest of the penultimate superior molar; in *Mesonyx* it is represented by a simple cone. The last superior molar of *Mesonyx* is triangular and not transverse, but the composition of the crown of that tooth in *Sarcothraustes* must be

known before the value of this character can be ascertained. If the view that *Sarcothraustes* has but three inferior premolars be correct, this character distinguishes it from *Mesonyx*, as do also the transversely expanded heels of the molars. The family *Mesonychidæ* may be for the present regarded as embracing the three genera of *Sarcothraustes*, *Mesonyx* and *Dissacus*.*

Char. Specif. The penultimate superior molar has a strong posterior cingulum which commences within the line of the internal bases of the external cusps, and rises into considerable importance behind the internal cusp. There is also an anterior cingulum which does not rise internally, and which is continuous with a strong external basal cingulum. The latter passes round the posterior base of the posterior cone, and runs into the posterior branch of the internal V. The posterior cone is smaller than the anterior cone, and its apex is well separated from the latter. The appearance of this tooth is something like that of a carnivorous marsupial.

The symphysis mandibuli slopes obliquely forwards, and is united by coarse suture. The ramus is stout and deep, as compared with the size of the molar teeth. The roots of the teeth are relatively large, especially those of the first two premolars. The crown of the canine is lost. The first premolar points forwards, nearly parallel with the canine, and divergent from the second premolar. The crown of the second premolar is small and subconic, and has a rudimental heel, and no anterior basal tubercle. The first true molar resembles considerably that of *Mesonyx*. There is a small anterior basal tubercle on the inner side of the principal cusp. The expansion of the heel is transverse only, there being no longitudinal lateral edges or tubercles. The enamel is obsoletely, rather coarsely wrinkled. There are two rather large mental foramina; the posterior below the anterior root of the first true molar, and the anterior below the posterior root of the second premolar.

Measurements.		M.
Diameters of superior M. ii	anteroposterior externally	.015
	transverse	.024
Anteroposterior diameter of base of M. iii		.0095
Anteroposterior diameter base of crown of inferior canine		.020
Length of bases of three inferior premolars		.038
Diameters inferior M. i.	anteroposterior	.019
	transverse	.0095
	vertical	.0110
Depth of ramus at P-m. iii		.0520
Width " "		.022

* American Naturalist, Dec., 1881.

CHAMPSOSAURUS PUERCENSIS, sp. nov.

I have already announced the discovery * of this Laramie genus in the Puerco beds of New Mexico, and described a species, *C. australis*, from that region. I now introduce two additional species from the same horizon. One of these is represented by a number of fragments which include three dorsal and four caudal vertebræ of apparently one individual. They represent an animal of larger size than any of those heretofore referred to *Champsosaurus*, excepting the *C. vaccinsulensis*. In all of the vertebræ the neural arch is more or less coössified with the centrum, and the animal had probably reached its full size.

One of the dorsal *centra* is split vertically and longitudinally, and shows the structure already figured by Leidy in the *Ischyrosaurus antiquus* † Leidy. The surface exposed displays two diagonal lines of fissure crossing each other at right angles. They indicate clearly the mode of origin of this amphiplatyan type of centrum. The centrum is first deeply amphicœlous as in the Theromorphous reptiles of the Permian. The conical cavities are filled by the ossification of the remaining portions of the notochord, forming a conical body which always remains distinct from the remainder of the centrum.

The articular faces of the dorsal centra are a little wider than deep, and the depth about equals the length of the body. They are not nearly so depressed as those of *C. australis*, and their outline is different. This is wider above and narrows below; in both *C. australis* and *C. saponensis* the inferior outline is part of a circle. None of the dorsals preserved are keeled below. There is a fossa below the diapophysis which has a subvertical posterior boundary. The general surface (somewhat worn) does not display wrinkles near the articular faces. An anterior dorsal has a short compressed diapophysis with a narrow figure 8 articular surface, and its superior border is in line with the roof of the neural canal. The anterior caudals have subround articular faces; the posterior are more oval and the bodies compressed. With greater compression, the length increases.

Measurements.		M.
Diameters of an anterior dorsal	anteroposterior	.025
	vertical	.025
	transverse	.030
Height of costal facet of do		.021
Diameters neural canal do.	vertical	.007
	transverse	.009
Diameters anterior caudal	anteroposterior	.024
	vertical	.021
	transverse	.021
Diameters posterior caudals	anteroposterior	.025
	vertical	.018
	transverse	.018

* American Naturalist, 1881. p. 669.
† Transac. Amer. Philos. Soc. 1860.

The typical specimen was found by Wm. Baldwin near the Puerco river, west of the Nacimiento mountain, New Mexico, in the typical locality of the Puerco formation.

CHAMPSOSAURUS SAPONENSIS, sp. nov.

Represented in my collection by six cervical and several dorsal vertebræ, one only of the latter with well preserved centrum, parts of ribs, and various other bones, whose reference is not yet certain.

The cervical vertebræ include the os dentatum or centrum of the atlas. This shows its streptostylicate character in its distinctness from both the centrum and the free hypapophysis of the axis. Nevertheless it is more Crocodilian than Lacertilian in form. Its anterior face is transverse, with a little lip carrying forwards the floor of the neural canal, below which the face is leveled posteriorly. The inferior surface is narrow and transverse, as though adapted for the anterior part of the hypapophysis of the axis. At each side it terminates in a prominent tuberosity, as though for the attachment of a cervical rib as in the Crocodilia. The anterior face is bounded posteriorly by a transverse groove which terminates in a fossa on each side. The posterior articular face of the os dentatum is wider than deep. The lateral angles of the superior face are rounded, and its median portion is concave.

The axis displays a large facet for the hypapophysis. Behind it the inferior middle line is not keeled, but is coarsely wrinkled longitudinally. The posterior edge of the hypapophysial facet is the most prominent part of the inferior surface. The posterior articular face is deeper than wide. This is true of the faces of all the cervical vertebræ. The latter gradually increase in size posteriorly, and the dorsals become larger. The articular faces of all the centra are regularly rounded and not contracted below. The five cervicals are strongly keeled below; the keel of the third centrum being split up anteriorly into narrow ridges. On the sixth the keel is more prominent and acute. The dorsal is not keeled. A trace of the parapophysis appears low down on the fourth cervical; it rises and becomes prominent as a round tuberosity on the fifth and sixth. It appears on the superior edge of the centrum of the dorsal vertebra, where it is connected with the diapophysis. It is near the middle of the length of the centrum, and not near the anterior border as in *C. australis*.

The surfaces of the vertebræ are very smooth excepting where thrown into coarse wrinkles near the borders of the articular faces and near the hypapophysis. The edges of the articular faces are somewhat revolute on the sides in the cervicals, but not on the dorsal. They are impressed in the centre to a point, most strongly so as we pass forwards in the series. There is a fossa below the space anterior to the parapophysis of the dorsal vertebra, which is abruptly bounded below by a horizontal angle. A separate neural spine perhaps of a cervical vertebra, has the following form. It is stout, and is contracted rather abruptly at the apex from behind forwards. The section is broadly lenticular, angulate in

front, and truncate behind. The posterior face has several longitudinal wrinkles, including a median raised line, and there are some more irregular wrinkles on the sides.

Measurements of vertebræ.	M.
Anterior face of os dentatum { width	.025
Anterior face of os dentatum { depth (oblique)	.012
Posterior face of os dentatum { width	.020
Posterior face of os dentatum { depth	.018
Length os dentatum above	.014
Diameters axis { posterior face { depth	.022
Diameters axis { posterior face { width	.020
Diameters axis { length	.0185
Hypapophysial facet os dentatum { depth	.008
Hypapophysial facet os dentatum { width	.014
Diameters fourth cervical { length	.022
Diameters fourth cervical { anterior { depth	.0225
Diameters fourth cervical { anterior { width	.022
Diameters sixth cervical { length	.0215
Diameters sixth cervical { anterior { depth	.0245
Diameters sixth cervical { anterior { width	.0235
Spaces between parapophysis and diapophysis of do	.0040
Diameters of dorsal { length	.0265
Diameters of dorsal { anterior { depth	.0260
Diameters of dorsal { anterior { width	.0265
Height of neural spine of ?, from postzygapophysis	.0210
Anteroposterior width of do. at base	.0100

The portions of ribs are separated heads and shafts. The former are double and therefore cervical, and are quite large. If the shafts belong to them, the neck of this species must have been wide. The shafts are slender and are of dense bone. The section is oval at the middle, but towards the distal extremity becomes flattened and grooved and delicately line ridged on one side. The extremities of the long bones are without condyles but have concave surfaces like those of the ribs. The bodies are robust and angular. They may be abdominal ribs of unusual stoutness. From the Puerco beds, D. Baldwin.

Stated Meeting, January 6, 1882.

Present, 8 members.

President FRALEY in the Chair.

Letters of acknowledgment were received from the Anthropological Institute of Great Britain and Ireland (XV, 3; 107, 108); and the Linnean Society, London (105, 106).

Letters of envoy were received from the Academie der Wissenschaften, Wien, Sept. 30, 1881; Bibliotheca Nazionale Vittorio Emanuele, Roma, Oct. 20, and the Meteorological Office, London, December, 1881.

A letter asking exchange of publications was received from the U. S. Geological Survey, Washington.

A circular letter asking exchange of publications was received from the Société des Sciences de Finlande, Helsingfors, Dec. 10, 1881.

A circular letter, dated December, 1881, was received from Prof. Dr. Rüdinger, in behalf of the Comité für die Jubiläumsfeier des Herrn Geheimraths Dr. Th. v. Bischoff.

Donations for the library were received from the Royal Society of New South Wales; the Academies at St. Petersburg, Berlin, Vienna and Turin; Observatories at St. Petersburg, Turin, and the Cape of Good Hope; Bibliotheca Speculæ Pulcovensis, in St. Petersburg; Imperial Society of Naturalists, Moscow; Naturforscher Verein, Riga; German Geological Society, Berlin; Zoologischer Anzeiger, Leipsig; Verein für Erdkunde, Halle a-S; Verein für Naturkunde zu Cassel; Zoological Garden, Frankfurt; Oberhessische Gesellschaft, Giessen; M. Hugo von Meltzel; Royal Venetian Institute; Royal Lombardy Institute; Museum of Natural History, and Revue Politique, Paris; Society of Commercial Geography, Bordeaux; Revista Euskara, Pamplona; Flora Batava, Leyden; Royal Asiatic, Royal Astronomical, Royal Geographical, Meteorological, Geological, Zoological, Linnean and Antiquarian Societies, and the Victoria Institute, Meteorological Office, and Nature, London; Mr. John Evans, F.R.S.; Royal Geological Society, Dublin; Mr. Horatio Hale, Clinton, Canada; American Oriental Society, and American Journal of Science, New Haven; Dr. J. S. Newberry, New York; Franklin Institute, and the "American," Philadelphia; American Chemical Journal, Baltimore; U. S. Geological Survey, Washington; "The Virginias," Staunton, Va.; American Antiquarian, Chicago; and the National Museum, Mexico.

The death of Dr. Isaac Israel Hayes, on Dec. 17, 1881, was announced.

Dr. Brinton was appointed to prepare an obituary notice of the deceased.

The death of Dr. John W. Draper, on Jan. 4, 1882, aged 71 years, was announced.

Dr. Hammond was appointed to prepare an obituary notice of the deceased.

An obituary notice of Mr. W. Milnor Roberts was read.

Prof. Cope presented a fossil lower jaw from the Colorado basin.

Nominations were read.

Mr. Lesley was nominated Librarian.

The report of the Finance Committee was submitted.

The Committee on the Deposit of MSS. reported progress.

And the meeting was adjourned.

An Obituary Notice of William Milnor Roberts.

(*Furnished by Mrs. W. Milnor Roberts, and read before the American Philosophical Society, by Frederick Fraley, January 6, 1882.*)

William Milnor Roberts, C. E., whose death occurred at Soledade, province of Minas Geraes, July 14th, 1881, was one of the oldest and most active members of the engineering profession. He was of Quaker descent, and was born in the city of Philadelphia on the 12th of February, 1810. His education was received in the best private schools of that city, during which a special course in mathematics of two terms was spent under the eminent mathematician, Joseph Roberts. He also pursued a course of architectural drawing in the first school established by the Franklin Institute, under the distinguished architect, John Haviland. After entering the profession of engineering—there were no engineering schools at that time—he continued his studies, principally in mathematics, of which he was very fond, during the winter months, the summer being spent in the field.

Owing to his aptitude for mathematical studies and investigations, his father's friend, Samuel Mifflin, then president of the Union canal company, of Pennsylvania, advised his adoption of the profession of civil engineering, an advice which he very wisely followed. He received his first employment in that profession on the Union canal, of Pennsylvania, in the spring of 1825, he being then in his sixteenth year. His first employment

was that of a chainman, his employer was the eminent canal engineer, Canvass White, and the chief of the party to which he was attached was Sylvester Welch. His progress in his profession from that time is shown by the fact that at the age of eighteen he was promoted by Mr. White to the charge of the most difficult section of the Lehigh canal, extending from Mauch Chunk down for a distance of sixteen miles. In 1829 he published a description of the Lehigh canal in *Hazard's Register*.

It was Mr. Roberts' rare good fortune to have been connected with the first railway enterprises in the United States, his career as an engineer being thus contemporaneous with the beginnings and growth of that greatest of agents in our modern civilization. Railway engineering in the United States began, in a crude way, in 1826 at the Quincy granite quarry, a tramway being then constructed for the transportation of stone from the quarry to the water, a distance of three or four miles. The first railway of any consequence, however, was the Mauch Chunk gravity road, nine miles in length, between the summit of Broad Top mountain and the head of the Mauch Chunk inclined plane. The first passenger car in the United States was put on this road in the early summer of 1827, and Mr. Roberts was one of the passengers on the first trip down the line. Since those first small beginnings, this first crude railway of nine miles, the railway system of the United States has grown to be the most powerful instrument of progress of our day, with its 95,000 miles of iron track netting the whole surface of the country and carrying wealth into almost every locality. Side by side with this wonderful material development, Mr. Roberts grew into eminence as an engineer, From his first beginning as a chainman, just one year before the first crude attempt at railway engineering, his career was one of steady, substantial growth until the closing hours of his life, crowned with the highest honors which his profession could bestow upon him, and ennobled by works whose perfection and usefulness will be an imperishable record of his worth and fame.

In the course of his long career of fifty-six years as an engineer, Mr. Roberts held so many and so varied positions of trust and responsibility that a bare enumeration of them would require more space than this brief sketch will admit. The more important of them may be summarized as follows: In 1829 Mr. Roberts' connection with the construction works of the Union and Lehigh canals was brought to a termination. In 1830 he was appointed resident engineer of the Union railroad and a feeder of the Union canal. From 1831 to 1834 he was senior principal assistant engineer on the Allegheny Portage railroad, during which time he had charge of repairs on the western division of the Pennsylvania State canal—from Johnstown to Pittsburgh—which had been damaged by the great flood of 1832. In 1835, in his 26th year, he received his first appointment as chief engineer, being called to fill that position on the Harrisburg and Lancaster railroad. In 1836 he accepted the chief engineership of the Cumberland Valley railroad which he held during that year and a part of 1837. During this time he planned and built the first combined railway and

common road bridge, which crossed the Susquehanna river at Harrisburg. From 1837 to 1841 he filled the office of chief engineer on the Monongahela river improvements, the Pennsylvania State canal construction works, the Erie canal, and the Ohio river improvements. In 1841–42 he was a contractor on the Welland canal (Canada) enlargement. In 1843–44 he was chief engineer for the Erie canal company, and from 1845 to 1847 he was chief engineer and trustees' agent for the Sandy and Beaver canal company, of Ohio. In 1848 he was appointed by the Legislature of Pennsylvania to make a survey to avoid, if possible, the Schuylkill (Philadelphia) inclined plane. In 1849 he declined the chief engineership of the first projected railroad in South America, to accept that of the Bellefontaine and Indiana railroad, of Ohio, where he remained until 1851. From 1852 to 1854 he was chief engineer of the Allegheny Valley railroad, consulting engineer for the Atlantic and Mississippi railroad, contractor for the whole of the Iron Mountain railroad, of Missouri, and chairman of a commission of three appointed by the Pennsylvania Legislature to examine and report upon routes for avoiding the inclined planes of the old Allegheny Portage railroad. From 1855 to 1857 he was contractor for the entire Keokuk, Des Moines and Minnesota railroad, consulting engineer for the Pittsburgh and Erie, and Terre Haute, Vandalia and St. Louis railroads, and chief engineer of the Keokuk, Mt. Pleasant and Muscatine railroad.

In December, 1857, Mr. Roberts sailed for Brazil to examine the route of the Dom Pedro II railway with the purpose of bidding for its construction. In 1858, as the senior member of a firm of American contractors, he concluded a formal contract in the United States with the Brazilian minister, Sr. Carvalho de Borges, for the construction of this road, and in the following year he returned to Brazil and took active charge of the work. He remained on the work, which exhibits some of the finest railway engineering and construction in the world, until the completion of the contracted work in 1864. During the remainder of 1864 and a part of 1865 he visited various railways and public works in Brazil and the Platine republics, returning to the United States in the latter part of 1865.

Soon after his arrival in the United States Mr. Roberts took charge of the surveys for the Atlantic and Great Western railroad, which he completed in April, 1866. After some miscellaneous work in the West, he was appointed in 1866 by the Secretary of War, Edwin M. Stanton, as United States civil engineer-in-charge of the Ohio river improvement, which position he held until 1870, when he resigned to accept the chief engineership of the Northern Pacific railroad. In 1868-69 he held, also, the position of associate chief engineer of the great bridge over the Mississippi at St. Louis. He retained the position of chief engineer of the Northern Pacific until his departure for Brazil in January, 1879. During his occupation of this last position he examined and reported upon several railways and the water supply of the cities of Pittsburgh and Philadelphia. In 1874 he was appointed by the President of the United States as a member of a commission of civil and military engineers to examine and report

upon plans for the improvement of the mouth of the Mississippi river. In 1877 he located the Nictaux and Atlantic railroad in Nova Scotia. During the year 1876 he held the position of vice-president in the American Society of Civil Engineers, and at the close of 1878 he was elected president of that society for the ensuing year.

Toward the close of 1878 Mr. Roberts accepted the appointment of the Brazilian Government for an examination of the ports and water-ways of the empire with reference to their improvement. His contract was for a period of three years, beginning with 1879, only six months of which remained unexpired at the time of his death. He left New York on the 4th of January, 1879, and arrived in this city on the 27th of the same month. He was at once charged with an examination of the port of Santos, and entered upon his new work in the following month of February. This task was completed in June, and on the 31st of August Mr. Roberts set out for an extended examination of the Upper Sao Francisco. He was accompanied on this survey by Prof. O. A. Derby, of the National Museum, Mr. Rudolf Wieser, assistant, and by several young Brazilian engineers. This survey was the most difficult and important one upon which Mr. Roberts was engaged, the field work alone occupying a period of over six months. After a long interval had elapsed, during which time he served on a commission to report upon the new water-works of this city, Mr. Roberts was commissioned with the examination of various northern ports, and in two separate trips made careful surveys of the ports of Pernambuco, Fortaleza, Maranhao, Victoria, Caravellas, and several other small ports.

Very recently he was instructed to examine the port of Rio Grande, but this work was afterwards deferred in order to have an examination made of the Rio das Velhas, province of Minas Geraes, during the season of low water. Accompanied by Prof. O. A. Derby, geologist, and Mr. J. W. de Aguiar, assistant, Mr. Roberts set out on this, his last survey, on the 2d of July, 1881. He was compelled to suspend his journey on the 7th, at a little settlement, or railway surveyors' camp, called Soledade, where an indisposition which had been troubling him for some days, developed into typhus fever. He died on the evening of July 14th, 1881, in the 72d year of his age, and was buried on the following day in the parish cemetery of Caramandahy, seven leagues beyond the city of Barbacena, Minas Geraes.

Stated Meeting, January 20, 1882.

Present, 7 members.

Vice-President, Mr. PRICE, in the Chair.

Letters were received from the Imperial Society of Naturalists of Moscow, dated Dec. 13, 1881, and January, 1882, asking the participation of this Society in the celebration of

the 50th Anniversary of Mr. Charles Renard's connection with their Society.

A letter was received from the Franklin Institute, dated Jan. 9, 1882, requesting Transactions XV, 3, and Parts 1 and 3 of the Catalogue.

Donations for the Library were received from the Naturforscher Vereins, Riga; Zoologischer Anzeiger, Leipzig; Academia dei Lincei, Roma; Société de Géographie, and Revue Politique, Paris; M. le Vicomte H. de Charencey; Royal Academy, Brussels; Journal of Forestry, Nature and the Greenwich Observatory, London; Natural History Society, and American Statistical Association, Boston; Museum of Comparative Zoölogy, and the Astronomical Observatory of Harvard College, Cambridge; Franklin Institute, American Journal of the Medical Sciences, Journal of Pharmacy, the "American," and the Directors of the Reading Railroad, Philadelphia; West Chester Philosophical Society; U. S. National Museum, Washington; and the Ministerio de Fomento, Mexico.

On motion of Prof. Kendall, Mr. Lesley was elected Librarian.

The following members were placed upon the Standing Committees:

Finance.	*Hall.*
Eli K. Price,	S. W. Roberts,
Henry Winsor,	J. S. Price,
John Price Wetherill.	W. A. Ingham.
Publication.	*Library.*
J. L. LeConte,	Eli K. Price,
D. G. Brinton,	C. P. Krauth,
E. Thomson,	R. S. Kenderdine,
C. M. Cresson,	E. J. Houston,
G. H. Horn.	Henry Phillips, Jr.

A letter from Dr. J. T. Rothrock, of December 20, 1881,

with a request for the loan of the Muhlenberg Herbarium to Dr. Gray of Harvard, was read; and it was, on motion,

Resolved, That the Secretary be authorized to deliver to the order of Dr. Gray, the Muhlenberg Herbarium, in whole or in part, on the receipt of his agent to return the same.

Resolved, That ten dollars be appropriated for the payment of the expense of labeling the Herbarium, in accordance with Dr. Gray's forthcoming work.

On scrutiny of the ballot-boxes the following persons were declared duly elected members of the Society:

Mr. William Blades, of London.
Mr. William Trautwine, of Philadelphia.
Rev. Samuel Savage Lewis, of Cambridge, England.
Mr. William Jefferis, of West Chester, Penn.
Hon. Washington Townsend, of West Chester, Pa.

And the meeting was adjourned.

Stated Meeting, February 3, 1882.

Present, 6 members.

President, Mr. FRALEY, in the Chair.

Letters of envoy were received from the Musée Guimet, dated Lyons, January 7, 1882; H. Scheffler, Braunschweig, December 6, 1881; and the Torrey Botanical Club, 7 Waverly Place, N. Y. City, January 21, 1882.

A letter of thanks for the action of the Society at its last meeting in regard to the Muhlenberg Herbarium, was received from Dr. Asa Gray, dated Cambridge, January 25, 1882.

A letter from Mr. Leighton Hoskins, dated Philadelphia, February 3, 1882, requesting the loan of the volumes of the Ercolano Bronzi in the Library, was referred to the Secretaries with power to act.

A circular letter was received from the Royal Society of New South Wales, dated Sidney, November 2, 1881.

Donations for the Library were received from the Depart-

ment of Mines, Melbourne; Royal Academies at Berlin, Rome, and Brussels; Zoologischer Anzeiger, Leipzig; Dr. Hermann Scheffler, Braunschweig; Revue Politique, Paris; Society of Commercial Geography, Bordeaux; Royal Astronomical Society, Cobden Club, and Nature, London; Natural History Society, Boston; Harvard College Library; American Journal, New Haven; Numismatic and Archæological Society, and Torrey Botanical Club, N. Y. City; Engineers' Club, Penn Monthly, the American, and Mr. Henry Phillips, Jr., Phila.; U. S. Census Bureau, Washington; and Prof. N. H. Winchell, St. Paul.

Prof. John Hagen's paper, "On the inclination of the apparent to the true horizon, and the errors rising thereof in Transit, Altitude and Azimuth-Observations," was submitted for the Proceedings.

Mr. Ashburner exhibited a specimen of Colorado Anthracite, and spoke of its composition.

Remarks on the subject were made by Messrs. Price and Britton.

Pending nomination No. 935 and new nominations Nos. 951 to 955, were read.

Mr. Henry Phillips, Jr., for the Committee on the Celebration of the Birthday of Franklin, made the following report, which was accepted and the Committee discharged.

JANUARY 28, 1882.

A special meeting of the Society was held this evening at six o'clock, at the Social Art Club, No. 1811 Walnut Street, pursuant to a resolution of the Society to celebrate the Birthday of Benjamin Franklin by a subscription dinner, at which were present:

President—Frederick Fraley.
Secretary—Daniel G. Brinton, M. D.
Curators—Charles M. Cresson, M. D., Henry Phillips, Jr.
Treasurer—J. Sergeant Price.
Councillors—Robert E. Rogers, M. D., Henry Winsor, William A. Ingham.
Members—S. D. Gross, M. D., Robert H. Allison, M. D., William Sellers, Eckley B. Coxe, William Pepper, M. D., C. N. Peirce, M. D., Joseph M. Wilson, J. Blodget Britton, Theo. G. Wormley, M. D., Wm. B. Rogers, Jr., B. B. Comegys, William Thomson, M. D., John Welsh, Morris

Longstreth, M. D., Henry Hartshorne, M. D., J. Price Wetherill, Carl Seiler, M. D., William Goodell, M. D., Frank Thomson, Robert Patterson, Edward D. Cope, Charles S. Wurts, M. D.

Dinner was then served, and interesting addresses were delivered by Frederick Fraley, President; S. D. Gross, M. D., Hon. John Welsh, Robert E. Rogers, M. D., William Pepper, M. D., Eckley B. Coxe, and E. D. Cope, and at 10 o'clock P. M. the meeting adjourned.

Mr. Ashburner introduced the subject of a bill before Congress for establishing a Government Bureau of Mines.

On motion of Mr. Price, the consideration of the propriety of the Society's recommending to Government either the establishment of such a bureau, or the establishment of an executive department to take charge of the agricultural, mining and commercial interests of the nation, was referred to a committee consisting of the President, Mr. Fraley, as Chairman, Mr. Ashburner and Mr. Price.

And the meeting was adjourned.

On the Inclination of the Apparent to the True Horizon and the Errors rising thereof in Transit, Altitude, and Azimuth-Observations. By John Hagen, S. J., College of the Sacred Heart, Prairie Du Chien, Wisconsin.

(*Read before the American Philosophical Society, February 3, 1882.*)

In the year 1875, Mr. Hann, editor of the "Zeitschrift der Oesterreichischen Gesellschaft für Meteorlogie," called attention to a special kind of irregularities in the figure of the earth, which hitherto were not sufficiently taken into account. According to him *the most important perturbation of the ellipsoidal level of the sea arises from the continents attracting the waters of the surrounding oceans.* (See Mittheilungen der geogr. Gesellsch. zu Wien, N. 12, 1875.) He supports his statement by the fact, that the continents are to be compared to large mountains, which by necessity, must disturb the level of the sea in the same way, as the Cordilleras of South America, the Apennines in Italy and the Shehallien in Scotland were able to deviate the plumb-line, and again by the fact, that the force of gravity on islands was in average found greater than was forecast by calculation, from which Dr. Hann concludes that the level of the oceanic islands be lower than that of the shores of the continents. He estimates in general the vertical distance between the disturbed and the undisturbed level of the sea

to more than one thousand meters, and finally proposes the following problem to be solved :

To find such an Ellipsoid of Revolution, 1, as has the volume of the Earth; 2, that the sum of the Earth's elevations and depressions with regard to this Ellipsoid become a minimum.

This problem, however, as given by the author, seems to be indetermined, unless a third condition is added, viz.: that the rotation axis of the Ellipsoid is parallel to that of the Earth and their centres coincide.

Mr. Hann is of the opinion that the solution of this problem would afford the solution of another problem, open already a century ago, viz.: the answer to the question, why the meridian mensurations and the observations of the second's pendulum, made on different points of the surface of the Earth, afford such different values for the compression of the Earth? These observations, he says, ought to be reduced not to the actual level of the sea, but to the level of that regular ellipsoid to be found by the above problem, whose compression could then be found from these observations with greater accordance.

The treatise here published is intended not to solve Hann's problem, but to take one step farther towards its solution. This solution seems to be an impossibility as long as the inclination of the apparent towards the true horizon is not known, for as many places as possible, both as to magnitude and direction. On the following pages, therefore, the formulas shall be developed by which both the influence of this inclination on astronomical observations will be shown and the way suggested, how to determine its magnitude and direction. Astronomers are well aware of the influence that the deviation of the plumb-line exerts on finding the longitude and latitude of a place and have begun to distinguish between the *geodetic* and the *astronomical* position of a place. By the latter expression they mean the longitude and latitude of the apparent horizon; in other words, the *apparent* longitude and latitude of a place.* It is, however, evident, that for parallactic observations and especially for the transits of Venus and Mercury, not the apparent but the true longitude and latitude are needed. Consequently the following pages, though not giving direct means for finding the true position of an observatory, might be of some interest, as they at least call attention to the errors caused by the inclination of the horizon on astronomical observations.

Let the pole of the true or mathematical horizon be denoted by Z, and that of the apparent, or as we may call it, physical horizon by Z′, then the arc Z Z′ represents the inclination of the latter towards the former as to magnitude and direction. We resolve it into two rectangular components, one of which α may lie in the vertical plane of the instrument used, its positive direction being towards the "sight-line" of the observer, while the other component, β, may be positive right-hand of the observer. In case of an artificial horizon part of the inclination α may be caused by the

*Note.—About this distinction see Chauvenet's Manual of Spherical and Practical Astronomy, Vol. 1, Art. 86, 160, 213.

instrument and the piers on which it rests, hence, the distance of the artificial horizon varying with the zenith distance of the object observed, this part of the inclination α will be a function of the zenith distance, while the rest as well as the inclination β will be the same for the same azimuth. Now it will not be difficult to convince oneself *that the inclination α cannot influence but the observation of zenith distances and the inclination β but that of azimuths and hour-angles.* Nor is it difficult to foresee, that the inclination α will have a similar effect as the flexure of the telescope and graduated circle on account of their gravity, while the inclination β is comparable to the inclination of the horizontal rotation axis to the true horizon. The former two are functions of the zenith distance and may therefore be represented by periodic series, whose terms involve the sines and cosines of its multiples, while the latter two are merely functions of the azimuth.

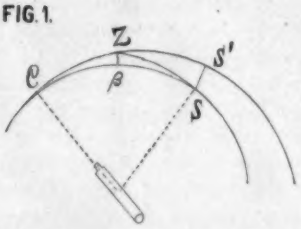
PART I.—*Influence of the inclination β on Azimuth- and Hour-angle Observations.*

We shall first suppose any altitude and azimuth instrument exactly adjusted so that the axis of collimation describes a great circle passing through the true zenith, and consider the influence exerted by the inclination of the artificial horizon on observations by reflection.

1. *Fundamental Formulas.*

If C denotes the point, in which the axis of collimation produced towards the eye-piece meets the celestial sphere, and Z the true zenith, the arc β will be perpendicular on the vertical plane C Z in the point Z. (Fig. 1.)

FIG. 1.



Again if through the end of the arc β and through C a great circle is put, the observed object S will be in this circle in the moment, when its reflected image passes over the middle thread of the telescope. From S let a perpendicular be drawn on the vertical plane of the instrument, which may be intersected in S', and let S and Z be joined by the arc of a great circle. Finally, let the small angles at Z and C be denoted respectively by d A and C, and β be taken positively right-hand of the observer. Then we are not to forget, that Z C = Z S, *i. e.*, equal to the true zenith distance z of the observed object in the moment of observation. Now in the isosceles triangle S Z C we have

$$\cos z = \cot C \sin d A - \cos z \cos d A,$$

or introducing the angle β instead of C by the formula

$$\tan \beta = \tan C \sin z$$

we have

$$(1 + \cos d A) \tan \beta = \tan z \sin d A,$$

or simpler,

$$d A = 2 \beta \cot z, \qquad (1)$$

which is the *correction of the azimuth*, for observations by reflection. There the azimuth is to be reckoned from south to west etc., and β right-hand of the observer.

The *correction of the hour-angle* may be derived from formula (1) by means of the well-known differential formula,

$$dt = \frac{\sin z}{\cos \delta \cos p} d A,$$

where p denotes the parallactic angle and δ the declination of the observed object. Thus we find

$$dt = 2 \beta \frac{\cos z}{\cos \delta \cos p} \qquad (2)$$

For upper or lower culminations we have $\cos p = 1$, hence

$$dt = 2 \beta \frac{\cos z}{\cos \delta}. \qquad (2^1)$$

For the sake of verification, this last formula may also be derived in the following way. Considering the great circle C Z S^1 as the meridian and joining S with the north pole N we have in the triangle S S^1 N

$$\sin dt = \frac{\sin S S^1}{\cos \delta}.$$

But in the triangle S S^1 C we have in like manner

$$\tan S S^1 = \tan C \sin 2 z,$$

since Z S^1 may be put equal to z and finally we have as above

$$\tan \beta = \tan C \sin z,$$

hence,

$$\tan S S^1 = \tan \beta \frac{\sin 2z}{\sin z} = 2 \tan \beta \cos z$$

and consequently by combining the first and last equation and supposing dt and β to be very small angles

$$dt = 2 \beta \frac{\cos z}{\cos \delta}. \qquad (2^1)$$

2. *The azimuth instruments.*

The correction of the azimuth for the observation by reflection

$$d A = 2 \beta \cot z \qquad (1)$$

has the meaning, that in such observations *the actual reading of the azimuth is by d A too small*, as long as β is positive right-hand of the observer.

If we now compare this correction with that for the inclination of the horizontal rotation axis to the true horizon we find both coincide except their constants. For if b denotes the elevation of the right-hand end of this axis above the true horizon, the correction of the azimuth is

$$d\,A = \mp\, b \cot z \begin{cases} - \text{ for direct image.} \\ + \text{ " reflected "} \end{cases}$$

as may be found in any Manual of Spherical Astronomy. Joining both corrections we have

for direct image $d\,A = -\,b \cot z$

" reflect. " $d\,A = (2\beta + b) \cot z = -\,(b - d) \cot z.$

if we put

$$d = 2\,(\beta + b) \qquad (3)$$

Hence the usual formula for correcting azimuth observations is to be modified for observations by reflection. For direct observations this formula is

$$a = A + \Delta A - b \cot z - c \operatorname{cosec} z, \qquad (4)$$

where a denotes the absolute azimuth of the observed object, A the actual reading, ΔA the index correction of the circle, so that $A + \Delta A$ denotes the azimuth counted from the meridian point of the circle. b denotes as above the elevation of the right-hand end above the true horizon and $90^\circ + c$ is the angle formed by the axis of collimation with this same end. Hence for observations by reflection we have

$$a = A + \Delta A - (b - d) \cot z - c \operatorname{cosec} z \qquad (5)$$

where z is not the reading of the vertical circle, but the zenith distance of the observed object. As we have defined the constant b as the inclination of the horizontal rotation axis to the *true* horizon, we, of course, cannot find it in the usual way with the striding level, this instrument being itself inclined to the true horizon by the unknown angle β. Hence we shall first find the constant $d = 2\,(\beta + b)$, which may be done in two ways, first by the striding level applied to the horizontal axis, which will give us

$$\beta + b = \tfrac{1}{2}\,d,$$

and secondly by observing the direct and reflected images of stars. Let θ be the sidereal time, when the direct image of a star passes over a certain azimuth and θ^1 the sidereal time, when the reflected image of the same star passes over the same azimuth, then we have the two equations

direct image $a = A + \Delta A - b \cot z - c \operatorname{cosec} z.$

reflect. " $a^1 = A + \Delta A - (b - d) \cot z^1 - c \operatorname{cosec} z^1.$

If now the observed star did not pass very near the zenith, we may neglect the two quantities

$$b\,(\cot z - \cot z^1) \text{ and } c\,(\operatorname{cosec} z - \operatorname{cosec} z^1)$$

as small of the second order and find by subtraction of the above equations

$$\frac{d}{2} = \beta + b = \frac{a^1 - a}{2} \tan z.$$

For z_0 may be taken the mean value of the two nearly equal zenith distances z and z^1, and if the instrument had no vertical circle, it may be computed from the declination, the latitude and the mean hour angle. Again we have

$$a^1 - a = \frac{d\,A}{dt}\,(\theta^1 - \theta),$$

where $\frac{d\,A}{dt}$ denotes the variation of the azimuth in the unit of time for the moment $\frac{1}{2}(\theta^1 + \theta)$.

Thus far it has been shown, how to find the value of d for one single azimuth, but it will be necessary to have the means of computing it for any azimuth. From the theory of the azimuth instruments it is known, that b is represented by the formula

$$b = i - i_0 \cos (A - A_0),$$

where i denotes the inclination of the horizontal axis to the azimuth circle, i_0 the inclination of this circle to the true horizon, while A is the azimuth of the observed object and A_0 a constant explained by the formula itself. The inclination β of the artificial horizon may be represented by a similar formula

$$\beta = -i_1 \sin (A - A_1), \qquad (6)$$

where i_1 is the constant deviation of the plumb line caused by local irregularities in the figure and density of the earth, A_1 the azimuth of its direction and A the azimuth of the observed object. Hence we find

$$\begin{aligned}\tfrac{1}{2}d = \beta + b &= i - i_0 \cos (A - A_0) - i_1 \sin (A - A_1)\\ &= i - \cos A\,(i_0 \cos A_0 - i_1 \sin A_1) - \sin A\,(i_0 \sin A_0 + i_1 \cos A_1)\end{aligned}$$

or if we put

$$\left.\begin{aligned} i_0 \cos A_0 - i_1 \sin A_1 &= i_2 \cos A_2\\ i_0 \sin A_0 + i_1 \cos A_1 &= i_2 \sin A_2\end{aligned}\right\} \qquad (7)$$

we find by a simple transformation

$$\tfrac{1}{2}\,d = \beta + b = i - i_2 \cos (A - A_2) \qquad (8)$$

To find the three constants i, i_2 and A_2 three observations are sufficient, which may be equally distributed in the usual way. Let d_1, d_2, d_3 be the values of d, corresponding to the three azimuths A, $A + 120^0$, $A + 240^0$ we find from (8)

$$\begin{aligned}\tfrac{1}{2}\,d_1 &= i - i_2 \cos (A - A_2)\\ \tfrac{1}{2}\,d_2 &= i + \tfrac{1}{2}\,i_2 \cos (A - A_2) + \tfrac{1}{2}\,i_2 \sin (A - A_2)\sqrt{3}\\ \tfrac{1}{2}\,d_3 &= i + \tfrac{1}{2}\,i_2 \cos (A - A_2) - \tfrac{1}{2}\,i_2 \sin (A - A_2)\sqrt{3}\end{aligned}$$

and by adding and subtracting these equations

$$\begin{aligned} i &= \tfrac{1}{6}\,(d_1 + d_2 + d_3)\\ i_2 \cos (A - A_2) &= \tfrac{1}{6}\,(d_2 + d_3 - 2d_1)\\ i_2 \sin (A - A_2) &= \frac{1}{2\sqrt{3}}\,(d_2 - d_3.)\end{aligned} \qquad (9)$$

If therefore either of the methods mentioned before, viz., by the striding

level or by observations of the direct and reflected image, is applied to three different azimuths, dividing the circle into three equal parts, the three constants i, i_2 and A_2 may be found by these formulas, and hence also the constant $\frac{1}{2}d$ may be computed for any azimuth by the formula

$$\tfrac{1}{2}d = i - i_2 \cos (A - A_2) \qquad (8)$$

Thus we see, that b cannot be obtained in the usual way, before the collimation constant c has been found. But if the time is known, we may succeed in finding c in the following way: Let θ be the sidereal time, when the direct image passes over any azimuth, and θ^1 the time, when the same star passes over the same azimuth of the reversed instrument, then we have the two equations

$$a = A + \Delta A - b \cot z - c \operatorname{cosec} z$$
$$a^1 = A + \Delta A - b \cot z^1 + c \operatorname{cosec} z^1.$$

If again the star in the moment of observation did not pass very near the zenith, the quantity b (cot z — cot z^1) may be neglected as small of the second order, hence we find by subtraction of the two equations

$$c = \tfrac{1}{2} (a^1 - a) \sin z_0$$

where z_0 is a mean value of z and z^1 and may be computed from the declination, the latitude and the mean hour-angle. Again we have

$$a^1 - a = \frac{d A}{dt} (\theta^1 - \theta)$$

where $\frac{d A}{dt}$ denotes the variation of the azimuth in the unit of time for the moment $\frac{1}{2} (\theta^1 + \theta)$.

If we now suppose the reading of the azimuth corrected as to the collimation constant, equation (4) becomes

$$a = A + \Delta A - b \cot z. \qquad (4^1)$$

Again, if we observe the time of transit over the same azimuth for different stars, any two observations will afford an equation of this form.

$$b = \frac{a^1 - a}{\cot z - \cot z^1} = (a^1 - a) \frac{\sin z^1 \sin z}{\sin (z^1 - z)}.$$

The factor of $(a^1 - a)$ will turn out very small, consequently, b will be found with great exactness, if any star near the zenith is combined with any near the horizon. The quantities a and z may be computed from the hour-angle t by the formulas

$$\sin z \sin a = \cos \delta \sin t$$
$$\sin z \cos a = -\cos \varphi \sin \delta + \sin \varphi \cos \delta \cos t,$$

where δ denotes the declination of the star and φ the latitude of the place. The latter equation may be changed into the following form, more convenient for logarithmic computation :

$$\sin z \cos a = -m \cos (\varphi + M),$$

if we put

$$\sin \delta = m \cos M, \quad \cos \delta \cos t = m \sin M.$$

If thus b is found for any azimuth, ΔA may be computed from (4¹).
Yet b varies with the azimuth and is represented by the formula

$$b = i - i_0 \cos (A - A_0).$$

The constant i is already known from the equations (9) and hence it is enough to find b for any two azimuths in order to find i_0 and A_0. If we choose the two azimuths A and $A + 90^0$, we find

$$b_1 - i = - i_0 \cos (A - A_0)$$
$$b_2 - i = + i_0 \sin (A - A_0),$$

by which equations the two quantities i_0 and A_0 are fully determined. Thus we are able to compute b for any azimuth by the formula

$$b = i - i_0 \cos (A - A_0).$$

But from (7) we have the equations

$$\left.\begin{aligned} i_1 \sin A_1 &= + i_0 \cos A_0 - i_2 \cos A_2 \\ i_1 \cos A_1 &= - i_0 \cos A_0 + i_2 \sin A_2 \end{aligned}\right\} \qquad (10)$$

by which we finally find i_1 and A_1, *i. e.*, the constant inclination of the apparent to the true horizon, as far as it is caused by irregularities in the surface of the Earth, and the azimuth of its direction. This constant inclination i_1 however, is not yet the total inclination Z Z¹, since large instruments together with their piers may cause an inclination of the artificial horizon variable with the zenith distance of the observed object, as will be seen in Part II.

Finally, attention must be called to two things. First, if the observations mentioned above are made on different days, the positions of the stars are to be reduced to a common epoch, best to the beginning of the year. Secondly, though we have found the formulas for finding the constant inclination of the apparent to the true horizon as to magnitude and direction, we are not to forget, that these formulas suppose the perfect knowledge of the latitude and time of the place.

3. *The Transit instrument in the Meridian.*

The correction of the hour-angle for observations by reflection

$$dt = 2 \beta \frac{\cos z}{\cos \delta} \qquad (2^1)$$

has the meaning, that in the moment, when the reflected image of any object passes over the middle thread of this instrument *its actual hour-angle is dt for upper transits and 180° + dt for lower transits*, if b is reckoned positive right-hand of the observer. Yet for these instruments the inclination β of the apparent horizon remaining always on the same side, it will be found more convenient to take β positive towards west and consequently to write the corrections for lower transits as follows:

$$dt = - 2 \beta \frac{\cos z}{\cos \delta}$$

while dt always denotes the increment of the hour-angle, which is reckoned in the usual way from south to west.

For upper culminations we have

$$z = +(\varphi - \delta) \text{ culmination south of the zenith}$$
$$z = -(\varphi - \delta) \quad " \quad \text{north} \quad " \quad "$$

and for lower culminations $z = 180^\circ - (\varphi + \delta)$, hence the corrections for the hour-angle are

$$\text{for upper culm, } dt = 2\beta \frac{\cos(\varphi - \delta)}{\cos \delta}$$
$$" \text{ lower } " \quad dt = 2\beta \frac{\cos(\varphi + \delta)}{\cos \delta}.$$

If again we compare this correction with the one for the rotation axis not lying parallel to the horizon, we find them coincident, except the constant. For if b denotes the elevation of the west end of the rotation axis above the *true* horizon, we have the usual formula for upper culminations

$$dt = \mp b \frac{\cos(\varphi - \delta)}{\cos \delta} \begin{cases} - \text{ for direct image} \\ + " \text{ reflect. } " \end{cases}$$

and for lower culminations

$$dt = \mp b \frac{\cos(\varphi + \delta)}{\cos \delta} \begin{cases} - \text{ for direct image} \\ + " \text{ reflect. } " \end{cases}$$

where dt has the same meaning as above. Joining the two corrections and putting $2(\beta + b) = d$, as before, we find

$$\left.\begin{array}{l} \text{For upper culminations.} \\ \text{direct image } dt = - \quad b \dfrac{\cos(\varphi - \delta)}{\cos \delta} \\ \text{reflect. } " \quad dt = -(b - d) \dfrac{\cos(\varphi - \delta)}{\cos \delta} \\ \text{For lower culminations.} \\ \text{direct image } dt = - \quad b \dfrac{\cos(\varphi + \delta)}{\cos \delta} \\ \text{reflect. } " \quad dt = -(b - d) \dfrac{\cos(\varphi + \delta)}{\cos \delta} \end{array}\right\} \quad (11)$$

where dt denotes the increment of the hour-angle. We need not consider separately the formulas for lower culmination, as we may deduce them from those for upper culmination at any time by simply substituting $180^\circ - \delta$ for δ.

In consequence of these considerations the formulas of Tobias Mayer, Bessel and Hansen are to be modified for observations by reflection as follows: Mayer's formula is the following

$$\tau = b \frac{\cos(\varphi + \delta)}{\cos \delta} + k \frac{\sin(\varphi - \delta)}{\cos \delta} + \frac{c}{\cos \delta}$$

where $\tau = -dt$ is the hour-angle east of the meridian, b the elevation of

the west end of the rotation axis above the true horizon, $90° - k$ the azimuth of this west end and $90° + c$ its angle with the line of collimation. Bessel's formula is

$$\tau = m + n \tan \delta + c \sec \delta,$$

and finally, Hansen's formula

$$\tau = b \sec \varphi + n (\tan \delta - \tan \varphi) + c \sec \delta,$$

where n denotes the declination of the west end of the rotation axis and $90° - m$ its hour-angle. All these constants are in the following relations to each other:

$$\left.\begin{array}{ll} n = b \sin \varphi - k \cos \varphi & b = \quad n \sin \varphi + m \cos \varphi \\ m = b \cos \varphi + k \sin \varphi & k = -n \cos \varphi + m \sin \varphi \end{array}\right\} \quad (12)$$

For observations by *reflection* the constant b and consequently m and n are to be changed, say into b^1, m^1, n^1, by the following formulas:

$$\begin{array}{l} b^1 = \quad -2\ \beta - b \qquad = b - d \\ m^1 = m - 2\ (\beta + b) \cos \varphi = m - d \cos \varphi \\ n^1 = n - 2\ (\beta + b) \sin \varphi = n - d \sin \varphi. \end{array}$$

Hence the three formulas of Mayer, Bessel and Hansen become for observations by *reflection*,

$$\tau = (b - d) \frac{\cos (\varphi - \delta)}{\cos \delta} + k \frac{\sin (\varphi - \delta)}{\cos \delta} + \frac{c}{\cos \delta}$$

$$\tau = m + n \tan \delta + c \sec \delta - d \frac{\cos (\varphi - \delta)}{\cos \delta}$$

$$\tau = (b - d) \sec \varphi + (n - d \sin \varphi) (\tan \delta - \tan \varphi) + c \sec \delta.$$

As to determining the constants of these formulas, it will be seen, as in case of the azimuth instruments, that they cannot be found, unless the time of the place be known. First we will find the constant d, which may be done in two different ways, viz: by the striding level, which, being itself inclined to the true horizon by the angle β, cannot give the value of b, but it gives the value of

$$\beta + b = \tfrac{1}{2} d;$$

or by observing the transits of the direct and reflected image of a star. Let T and T^1 be the mean values of time for all the transits reduced to the middle thread for direct and reflected image, ΔT the clock correction on sidereal time and a the star's apparent right ascension, then is evidently $a = T + \Delta T + \tau$, hence

$$\text{for direct image } a = T + \Delta T + b \frac{\cos (\varphi - \delta)}{\cos \delta} + k \frac{\sin (\varphi - \delta)}{\cos \delta} + \frac{c}{\cos \delta}$$

$$\text{“ reflect “ } a = T^1 + \Delta T + (b - d) \frac{\cos (\varphi - \delta)}{\cos \delta} + k \frac{\sin (\varphi - \delta)}{\cos \delta} + \frac{c}{\cos \delta}$$

and by subtraction

$$\frac{d}{2} = \beta + b = \frac{T^1 - T}{2} \frac{\cos \delta}{\cos (\varphi - \delta)} \quad (13)$$

which determination will be the more exact, the greater $\cos(\varphi - \delta)$, *i. e.* the nearer the observed star passed by the zenith.

The collimation constant is found in the usual way either by reversing the axis, or by using two horizontal collimating telescopes, and the constant n by observations of the upper and lower culmination. If then, we suppose the times of transit already corrected as to the errors arising from c and n, we find from Bessel's formula

$$\text{for direct image } a = T + \Delta T + m$$

$$\text{" reflect. " } a = T^1 + \Delta T + m - d\,\frac{\cos(\varphi - \delta)}{\cos\delta}$$

and from Hansen's formula

$$\text{for direct image } a = T + \Delta T + b \sec\varphi$$

$$\text{" reflect. " } a = T^1 + \Delta T + (b - d) \sec\varphi.$$

By these formulas it is made evident, that *neither m nor b can be found independently of the clock correction.* But if this is known, Bessel's formula will give the constant m, or Hansen's formula b. The azimuth constant k may be determined by observations of upper and lower transits or be computed from (12). Thus, b being found, we may finally determine

$$\beta = \frac{d}{2} - b.$$

i. e. the west inclination of the apparent to the true horizon.

4. *The Transit Instrument in the Prime Vertical.*

From the general formula

$$dt = 2\,\beta\,\frac{\cos z}{\cos\delta\cos p} \qquad (2)$$

we shall obtain the formula for the transit instrument in the prime vertical by finding the value of cos p for the azimuth $A = 90^\circ$ and substituting it in the above formula. We have in general

$$\cos p \sin z = \cos\delta \sin\varphi - \sin\delta\cos\varphi\cos t.$$

But for the prime vertical we have the three special equations

$$\sin z = \cos\delta \sin t$$

$$\cos\delta = \frac{\cos\varphi\cos z}{\cos t}$$

$$\sin\delta = \sin\varphi\cos z.$$

Substituting these quantities successively into the three members of the general equation we find

$$\cos p \cos\delta = \sin\varphi\cos\varphi\cos z\tan t.$$

But from the three formulas for the prime vertical follows

$$\tan t = \frac{\tan z}{\cos\varphi}$$

consequently,

$$\cos p \cos\delta = \sin\varphi \sin z,$$

hence we have for observations by reflection with the transit instrument in the prime vertical the correction of the hour-angle.

$$dt = \frac{2\beta}{\tan z \sin \varphi} \qquad (14)$$

The meaning of this correction is, that in the moment, when the reflected image of any object passes the middle thread of this instrument, *the actual hour-angle of the object observed is* $90^\circ + dt$ *or* $270^\circ + dt$, β being positive right-hand of the observer. Yet as also for this instrument the inclination β of the apparent horizon remains always on the same side, it will be found more convenient to take β positive towards north and consequently to write the correction of the hour-angle as follows:

$$dt = \pm \frac{2\beta}{\tan z \sin \varphi} \begin{cases} + \text{ Star west} \\ - \text{ " east.} \end{cases}$$

If we now compare this correction with the one for the rotation axis not lying parallel to the horizon, we find them coinciding except their constants. Let θ denote the sidereal time, when the star passed over the true prime vertical, and T the clock time, when it passed the middle thread of the instrument, and finally, Δ T the correction of the clock on sidereal time, then the theory of this instrument gives us these formulas for *direct* observations

$$\theta = T + \Delta T + \frac{b}{\tan z \sin \varphi} + \frac{k}{\sin \varphi} + \frac{c}{\sin z \sin \varphi} \text{ Star west}$$

$$\theta = T + \Delta T - \frac{b}{\tan z \sin \varphi} + \frac{k}{\sin \varphi} - \frac{c}{\sin z \sin \varphi} \text{ " east}$$

where b denotes the elevation of the north end of the rotation axis above the true horizon, $180^\circ - k$ the azimuth of this same end, and $90^\circ + c$ its angle with the sight-line of the telescope. For observations by reflection, $180^\circ - z$ is to be substituted for z, which changes only the sign of b. But besides this, the artificial horizon being inclined to the north, the reflected image will be observed after the star passed over the prime vertical in the west and before it passed over the same in the east. Hence, if we put $d = 2(\beta + b)$ as before, the first fraction of the above equations becomes

$$-\frac{b + 2\beta}{\tan z \sin \varphi} = +\frac{b - d}{\tan z \sin \varphi} \text{ Star west}$$

$$+\frac{b + 2\beta}{\tan z \sin \varphi} = -\frac{b - d}{\tan z \sin \varphi} \text{ " east.}$$

Hence the two formulas for the transit instrument in the prime vertical are to be modified for *observations by reflection* in the following way:

$$\theta = T + \Delta T + \frac{b - d}{\tan z \sin \varphi} + \frac{k}{\sin \varphi} + \frac{c}{\sin z \sin \varphi} \text{ Star west}$$

$$\theta = T + \Delta T - \frac{b - d}{\tan z \sin \varphi} + \frac{k}{\sin \varphi} - \frac{c}{\sin z \sin \varphi} \text{ " east.}$$

Also in this case we shall see, that the constants cannot be found without

the time and latitude of the place being known. First d may be determined, as in former cases, either by the striding level, which will give the angle

$$\tfrac{1}{2}\,d = b + \beta,$$

or by observing the direct and reflected image of a star either in west or in east. By subtracting the two corresponding equations we find

$$\frac{d}{2} = \beta + b = \frac{T^1 - T}{2} \tan z \sin \varphi,$$

where stars are to be chosen, that pass near the zenith, The collimation constant c may be determined by reversing the axis and observing in both cases the time of transit. As in this case the sign of c alone is changed, we find by subtracting the two corresponding equations

$$c = \frac{T^1 - T}{2} \sin z \sin \varphi,$$

where stars passing near the zenith are again preferable. Both operations may be performed by first observing the transits over some threads and then, after having moved the instrument, over the rest, and by reducing them to the middle thread, or if the observations are taken on different days, the rate of the clock must be known and added to the observed time.

Let us now suppose the time T being already corrected as to the collimation, then by observing the same star east and west we may find both constants b and k. In this case the equations are

$$\theta = T + \Delta T + \frac{b}{\tan z \sin \varphi} + \frac{k}{\sin \varphi} \text{ Star west,}$$

$$\theta^1 = T^1 + \Delta T - \frac{b}{\tan z \sin \varphi} + \frac{k}{\sin \varphi} \quad \text{“ east.}$$

By subtracting we have

$$b = \tan z \sin \varphi \,[\tfrac{1}{2}(\theta - \theta^1) - \tfrac{1}{2}(T - T^1)].$$

Should the clock corrections not be the same T^1 were to be corrected by the rate. Now $\frac{1}{2}(\theta - \theta^1) = t$ is the hour-angle of the star in the moment when it passes over the true prime vertical and may be computed from the latitude of the place and the star's declination by the formula

$$\cos t = \frac{\tan \delta}{\tan \varphi}$$

or better still from the formula

$$\tan \tfrac{1}{2} t^2 = \frac{\sin(\varphi - \delta)}{\sin(\varphi + \delta)}.$$

The errors in the observation of $T - T^1$ will also here be the smaller, the smaller tan z, *i. e.* the nearer the star passes the zenith. Now d and b being known we find the north inclination of the apparent horizon

$$\beta = \tfrac{1}{2}\,d - b.$$

By adding the above equations we find

$$k = \sin \varphi \, [\tfrac{1}{2} (\theta + \theta^1) - \tfrac{1}{2} (T + T^1) - \Delta T],$$

or as $\frac{1}{2} (\theta + \theta^1) = a$ is the star's right ascension

$$k = \sin \varphi \, [a - \tfrac{1}{2} (T + T^1) - \Delta T].$$

PART II.—*Influence of the inclination α on Altitude Observations.*

By α we have denoted that component of the inclination Z Z^1 of the apparent to the true horizon, which lies in the vertical plane of the instrument used. With large instruments part of this component may be caused by the instrument and its piers, and is, therefore, as was explained in the beginning, depending on the zenith distance of the object observed. The other part of α is according to former notations [see formula (6)]

$$q = i_1 \cos (A - A_1) \qquad (15)$$

and is caused by the constant local irregularities in the figure and density of the earth. The first part of α will have an effect on altitude observations quite analogous to the flexure of the instrument. This latter correction is generally represented by the series

$$\begin{aligned} &a^1 \cos z + a^{11} \cos 2 z + a^{111} \cos 3 z + \ldots \\ &+ b^1 \sin z + b^{11} \sin 2 z + b^{111} \sin 3 z + \ldots \end{aligned}$$

and its sign is understood so, that if z is the reading of the zenith distance of a star

$$z + a^1 \cos z + \ldots + b^1 \sin z + \ldots.$$

represents the true zenith distance freed from flexure. If for instance N denotes the reading of the Nadir point (for which $z = 180^\circ$,)

$$N - a^1 + a^{11} - a^{111} + \ldots$$

will represent the true nadir freed from flexure.

By a similar formula the component α may be represented this way

$$\left.\begin{aligned} \alpha = q &+ a_1^1 \cos z + a_1^{11} \cos 2 z + a_1^{111} \cos 3 z + \ldots \\ &+ b_1^1 \sin z + b_1^{11} \sin 2 z + b_1^{111} \sin 3 z + \ldots \end{aligned}\right\} \qquad (16)$$

For the nadir ($z = 180^\circ$) we have

$$\alpha_0 = q - a_1^1 + a_1^{11} - a_1^{111} + \ldots$$

Now let z denote the reading of the instrument, ζ the true zenith distance of the object S observed, and N the reading of the nadir, then we shall have for direct observations (Fig. 2).

$$\begin{aligned} &z + a^1 \cos z + a^{11} \cos 2 z + a^{111} \cos 3 z + \ldots \\ &+ b^1 \sin z + b^{11} \sin 2 z + b^{111} \sin 3 z + \ldots \\ &- (N + 180^\circ - a^1 + a^{11} - a^{111} + \ldots) + \alpha_0 = \zeta \end{aligned}$$

Again let z^1 be the reading of an observation by reflection and we shall have

$$\begin{aligned} &z^1 - a^1 \cos z + a^{11} \cos 2 z - a^{111} \cos 3 z + \ldots \\ &+ b^1 \sin z - b^{11} \sin 2 z + b^{111} \sin 3 z - \ldots \\ &- (N + 180^\circ - a^1 + a^{11} - a^{111} + \ldots) + \alpha_0 = 180^\circ - \zeta + 2 \alpha \end{aligned}$$

Let now the rotation axis of the instrument be reversed so that the graduation runs in the contrary direction and z^{II} be the reading of a direct observation and we shall have

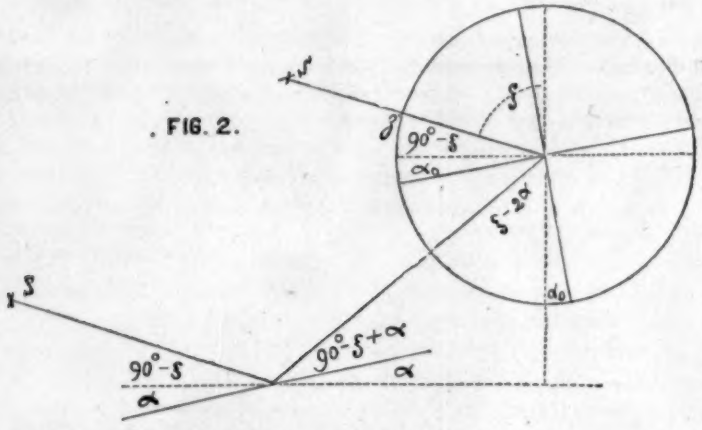
$$z^{II} + a^{I} \cos z + a^{II} \cos 2z + a^{III} \cos 3z + \ldots$$
$$- b^{I} \sin z - b^{II} \sin 2z - b^{III} \sin 3z - \ldots$$
$$- (N + 180^\circ - a^{I} + a^{II} - a^{III} + \ldots) - a_0 = 360^\circ - \zeta$$

Let finally z^{III} be the reading of an observation by reflection in the same position of the instrument, and we shall have

$$z^{III} - a^{I} \cos z + a^{II} \cos 2z - a^{III} \cos 3z + \ldots$$
$$- b \sin z + b^{II} \sin 2z - b^{III} \sin 3z + \ldots$$
$$- (N + 180^\circ - a^{I} + a^{II} - a^{III} + \ldots) - a_0 = 180^\circ + \zeta - 2a$$

But from the explanations in the first part, it is evident, that with obser-

FIG. 2.



vations by reflection a star is observed out of the vertical plane of the instrument, so that the azimuth of the star is by

$$d A = 2 \beta \cot z$$

greater than the azimuth of the reading. Hence, if we want to compare with each other the four equations given above, we are to reduce all the zenith distances to the same azimuth. This may be effected by the well-known formula

$$dz = \tan p \sin z \, d A,$$

which by substituting the above value of $d A$ becomes

$$dz = 2 \beta \tan p \cos z. \qquad (17)$$

Here, as in Part I, p denotes the parallactic angle. The meaning of formula (17) is not, as if the inclination β of the artificial horizon could prevent the observer from reading the actual zenith distance of the star, it means that the actual zenith distance is by dz greater, than it would be, if the star were still in the azimuth of the instrument.

Hence, with the two observations by reflection mentioned above, the readings z^{I} and z^{III} are to be diminished by $2\,\beta \tan p \cos z$, in order to have in all the four equations the same true zenith distance belonging to the same azimuth. If the observation by reflection is taken in the meridian, where tan p is very small, this correction may be omitted as small of the second order. The same value of dz may also be found by the usual differential formula

$$dz = \cos\delta \sin p\, dt$$

and the following formula, which was developed above

$$dt = 2\,\beta \frac{\cos z}{\cos\delta \cos p}.$$

If for brevity's sake we denote the apparent zenith point, corrected as to flexure, by Z_1 and put

$$Z_1 = 180^\circ + N - a^{I} + a^{II} - a^{III} + \ldots$$

our four equations mentioned several times will become

$$\left.\begin{aligned}
\zeta = z \;&+ a^{I}\cos z + a^{II}\cos 2z + a^{III}\cos 3z + \ldots \\
&+ b^{I}\sin z + b^{II}\sin 2z + b^{III}\sin 3z + \ldots \\
&- Z_1 + a_o. \\
180^\circ - \zeta = z^{I} \;&- (a^{I} - 2a_1^{I})\cos z + (a^{II} - 2a_1^{II})\cos 2z - \ldots \\
&+ (b^{I} - 2b_1^{I})\sin z - (b^{II} - 2b_1^{II})\sin 2z + \ldots \\
&- Z_1 - 2q + a_o - 2\beta \tan p \cos z. \\
360^\circ - \zeta = z^{II} \;&+ a^{I}\cos z + a^{II}\cos 2z + a^{III}\cos 3z + \ldots \\
&- b^{I}\sin z - b^{II}\sin 2z - b^{III}\sin 3z - \ldots \\
&- Z_1 - a_o. \\
180^\circ + \zeta = z^{III} \;&- (a^{I} + 2a_1^{I})\cos z + (a^{II} + 2a_1^{II})\cos 2z - \ldots \\
&- (b^{I} + 2b_1^{I})\sin z + (b^{II} + 2b_1^{II})\sin 2z - \ldots \\
&- Z_1 + 2q - a_o - 2\beta \tan p \cos z.
\end{aligned}\right\} \quad (18)$$

These equation are sufficient to find the probable values of the constants a, b, a_1 and b_1 by observations of different stars. The constants a however can be eliminated, so that, to find zenith distances, we need not know but the constants b and q. For we find

$$\zeta - 180^\circ = \tfrac{1}{2}(z - z^{II}) + b^{I}\sin z + b^{II}\sin 2z + b^{III}\sin 3z + \ldots + a_o \quad (19)$$

The b being found by this equation, the constants a, may be found by the following one

$$\begin{aligned}
-\zeta = \tfrac{1}{2}(z^{I} - z^{III}) &+ 2a_1^{I}\cos z - 2a_1^{II}\cos 2z + \ldots \\
&+ b^{I}\sin z - b^{II}\sin 2z + \ldots - 2q + a_o.
\end{aligned}$$

The constants a may be determined from

$$180^\circ = \tfrac{1}{2}(z + z^{II}) + a^{I}\cos z + a^{II}\cos 2z + \ldots - Z_1$$

and afterwards also the b_1 from

$$\begin{aligned}
180^\circ = \tfrac{1}{2}(z^{I} + z^{III}) &- a^{I}\cos z + a^{II}\cos 2z - \ldots \\
&- 2b_1^{I}\sin z + 2b_1^{II}\sin 2z - \ldots - Z_1 - 2\beta \tan p \cos z.
\end{aligned}$$

The equations (18) and all the others developed from them show, that

the true zenith distance ζ cannot be separated from the constant a, or, to speak more exactly, from the constant q, they giving always the value of $\zeta - q$. Nor will it be possible to separate zenith distances from this inclination by *sextants* or *reflecting circles*. The inclination β perpendicular to the plane of the sextant or reflecting circle has indeed no influence on finding altitudes, yet this is the case with the inclination α in the plane of the instrument, all the readings of altitudes being too great by the angle α, if an artificial horizon is used, while in case of a sea horizon the dip will be affected by this inclination. Neither of these errors can be eliminated by these instruments. Thus by altitude observations the inclination of the artificial horizon may be found *as far as it depends on the attraction of the instrument and its piers*, but not as far as it depends on local irregularities of the earth.

Now to come to a conclusion, the question turns up to the astronomer, by what means he will find the latitude and the time of his place. Since in case that his apparent meridian line is not parallel to the true horizon, all observations of stars will give him the latitude not of his place, but of such places, whose true horizon is parallel to his apparent meridian line. And in like manner if the plane of his apparent meridian does not go through the centre of the earth, all observations of stars will furnish him with the time not of his place, but of such places as are lying in a plane parallel to his apparent meridian and touching the centre of the earth. Consequently, all the methods of finding the longitude by immediate transportation of time or by observation of signals *visible at the same instant* will give him the longitude not of his place, but of the places just defined.

He must therefore look out for other means to find the errors in the determination of the latitude and the longitude of his place, and consequently also the constants of correction for his instruments, and such means seem to be *geodetic mensurations* and the observation of *parallactic phenomena*. If as many places of the earth as possible are combined by such observations and mensurations and the condition is made, that the sum of the squares of differences between the calculated and observed longitudes and latitudes becomes a minimum, the probable errors in determining the position of these places may be found. The first method has been partially employed by Prof. Schmidt in Göttingen and later also by the U. S. Coast Survey.* On the instigation of the celebrated Gauss Prof. Schmidt made use of the different meridian mensurations to calculate the dimensions of the terrestrial ellipsoid, so that the sum of the squares of differences between the computed and observed latitudes was a minimum. He found for the mean error of latitudes $3''.193$. But it may be interesting to have the complete result of his computation here reprinted from his "Lehrbuch der mathem. u. phys. Geography, Göttingen, 1829, I. p. 199."

* Report for 1853.

Tarqui	3°	4′	30″.83 + 1″.87
Cotchesqui	0	2	37.83 — 1.87
Trivandeporum	11	44	52.59 — 0.58
Paudree	13	19	49.02 + 0.57
Punnæ	8	9	38.39 — 1.78
Putchapolliam	10	59	48.93 — 1.22
Dodagoontah	12	59	59.91 + 3.54
Namthabad	15	6	0.64 — 0.54
Formetera	38	39	56.11 + 3.40
Montjouy	41	21	45.45 + 2.55
Barcelona	41	23	47.16 + 0.82
Perpignan	42	41	58.01 — 4.16
Carcassone	43	12	54.31 — 1.02
Evaux	46	10	42.19 — 5.88
Pantheon	48	50	48.94 + 0.37
Dünkirchen	51	2	8.74 + 3.92
Göttingen	51	31	47.85 — 2.76
Altona,	53	33	45.27 + 2.76
Dunnose	50	37	8.21 — 1.86
Greenwich	51	28	40.00 + 0.94
Blenheim	51	50	27.09 + 3.01
Arburyhill	52	13	28.19 + 1.83
Clifton	53	27	31.99 — 3.91
Mallörn	65	31	31.06 + 1.31
Pahṭawara	67	8	51.41 — 1.31

In like manner also mensurations of Parallels might serve to find the errors in longitude. Amongst the *parallactic* phenomena, which may contribute towards finding the errors in longitude and latitude, especially solar eclipses and occultations of stars are to be mentioned. If in the equation, which represents the condition of a certain place of the earth lying in the surface of the cone of shadow, not only the longitude, but also the latitude and sidereal time, are supposed to be erroneous,* very likely part of the errors, for which formerly the ephemerides were made responsible, must be ascribed to the inclination of the apparent horizon. Thus longitude and latitude of an Observatory being approximately corrected by any of these methods, the formulas given in the preceding pages will furnish the means of finding the constants of correction for the instruments, and finally also *the inclination of the apparent to the true horizon as to magnitude and direction.*

* Brünnow in his "Lehrbuch der Sphärischen Astronomie," p. 320, develops this equation, supposing only the Ephemerides to be erroneous, Chauvenet in his "Manual of Spherical and Practical Astronomy," 5th ed. vol. I, p. 523, regards the corrections of the coördinates of the place of observation as depending only upon the correction of the eccentricity of the terrestrial meridian, supposing the latitude itself as well as the sidereal time to be correct.

Stated Meeting, February 17, 1882.

Present, 8 members.

Vice-President, Prof. KENDALL, in the Chair.

Letters accepting membership were received from Mr. Wm. W. Jefferis, dated West Chester, Pa., Jan. 25, 1882; and from Mr. W. Townsend, West Chester, Pa., Jan. 25, 1882.

The resignation of Rev. Samuel Longfellow from the Society was announced.

Letters of envoy were received from the Imperial Botanical Garden, St. Petersburg, dated, Dec. 22, 1881; and the Department of the Interior, Feb. 9, 1882.

Letters and postals acknowledging the receipt of Proceedings, No. 109, were received from the Geological Survey of Canada; Maine Historical Society; New Hampshire Historical Society; Boston Public Library; Boston Athenæum; Museum of Comparative Zoology, Cambridge; Essex Institute, Salem; American Antiquarian Society, Worcester; Rhode Island Historical Society, and Brown University, Providence; Connecticut Historical Society, Hartford; University of the City of New York; New York Hospital; Astor Library; Prof. J. J. Stevenson; U. S. Military Academy, West Point; Mr. C. H. F. Peters, Clinton, New York; New Jersey Historical Society, Newark; Pennsylvania Historical Society, Philadelphia; Mr. Geo. Smith, Garrettford P. O., Pa.; Prof. C. L. Doolittle, Bethlehem, Pa.; Prof. Trail Green, Easton, Pa.; Mr. J. F. Carll, Pleasantville, Pa.; Maryland Historical Society, Baltimore; Mr. Wm. B. Taylor, Washington; Georgia Historical Society; Prof. J. M. Hart, Cincinnati; Dr. Robert Peter, Lexington; Mr. Danl. Kirkwood, Bloomington, Ind.; Chicago Historical Society; Prof. J. S. Campbell, Crawfordville, Ind.; and the Wisconsin Historical Society, Madison.

A letter dated, Feb. 3, 1882, was received from Prof. E. D. Cope, making a request that No. 95 of the Proceedings, containing Dr. Gabb's paper on Costa Rica, should be sent to Mr. Leon Fernandez, San José, Costa Rica, as he is preparing a history of that country.

A letter was received from the Librarian of Cornell College Library, concerning the completion of their sets of Proceedings and Transactions.

A letter was received from C. Zinckra, dated Leipsig, Jan. 22, 1882.

Circular letters were received from the Smithsonian Institution, Washington.

Donations for the Library were received from the Asiatic Society of Japan; St. Petersburg Imperial Botanical Garden; Swedish Bureau of Statistics; Zoologischer Anzeiger, Leipsig; Accademia dei Lincei, Rome; Société de Géographie, Annales des Mines, and Revue Politique, Paris; Revista Euskara, Pamplona; London Nature; Natural History Society, and Mr. Samuel Abbott Green, Boston; Essex Institute, Salem; New York Academy of Sciences; New Jersey Historical Society; Numismatic and Antiquarian Society, American Journal of Pharmacy, "The American," and Mr. Henry Phillips, Jr., Philadelphia; Mr. John H. B. Latrobe, Baltimore; Department of the Interior, Washington; and the Ohio Mechanics Institute, Cincinnati.

Mr. Britton exhibited some peats and lignites of Arkansas, and some Anthracites from the same State, and also some bituminous coals, showing the progress of the formation of coals.

Pending nominations, Nos. 935, 951–955 were read.

Report of the Officers and Council was read.

And the meeting was adjourned.

Stated Meeting, March 3, 1882.

Present, 7 members.

President, Mr. FRALEY, in the Chair.

The death of Robert Bridges, M.D., on February 20, 1882, in the 76th year of his age, was announced by the President.

The death of Mr. Thos. P. James, at Cambridge, Mass., on February 22, 1882, in the 79th year of his age, was announced by Mr. Briggs.

The President was authorized to appoint suitable persons to prepare obituary notices of each of the deceased.

A letter of envoy was received from the Musée Guimet, Lyons, dated February 3, 1882.

Letters of acknowledgment were received from the Offenbacher Verein für Naturkunde (108); American Statistical Association, Boston (109); Mr. T. P. James (109); Yale College Library, New Haven (109); Mr. Henry Phillips, Jr., Philadelphia (109); and the Wyoming Historical and Geological Society, Wilkesbarre, Pa. (108, 109).

A letter was received from the Librarian of the Franklin Institute, dated February 21, 1882, requesting Part 1st of the Catalogue. On motion it was ordered to be furnished.

Donations for the Library were received from the Editor of Zoologischer Anzeiger, Leipsig; Accademia dei Lincei, Rome; Révue Coléopterologique, Brussels; Wurttembergische Vierteljahrshefte für Landesgeschichte, Stuttgart; Revue Politique, Paris; Société de Géographie Commerciale, Bordeaux; Royal Academy of History, Madrid; Cobden Club, Journal of Forestry, and Nature, London; Prof. C. Schorlemmer, Manchester, England; Royal Dublin Society; Natural History Society, and Rev. E. F. Slafter, Boston; American Journal, New Haven; Franklin Institute, the American, Prof. E. D. Cope, Mr. J. Blodgett Britton, and Mr. Henry Phillips, Jr., Philadelphia; Johns Hopkins University, Baltimore; U. S. National Museum, Sensus Bureau, Bureau of Education, U. S. Commission of Fish and Fisheries, and the War Department, Washington; Revista Cientifica Mexicana, Revista Mensual Climatologica, and Ministerio de Fomento, Mexico.

A necrological notice of the late Dr. John W. Draper, by Dr. Wm. A. Hammond, was read.

Prof. E. D. Cope read a paper entitled "On the Structure of some Eocene Carnivorous Mammals," illustrating his subject by the exhibition of various fossil remains.

New nomination No. 956, was read.

Pending nominations Nos. 935, and 951 to 955, were read.

And the meeting was adjourned.

An Obituary Notice of John W. Draper, M.D., LL.D. By William A. Hammond, M.D., Surgeon General U. S. Army (Retired List).

(*Read before the American Philosophical Society, March 3, 1882.*)

In the death of Dr. Draper, the American Philosophical Society has to regret the loss of one of its most distinguished members. He died at his residence at Hastings-on-the-Hudson, in the State of New York, on the fourth day of January, 1882, after an illness which had lasted with more or less severity for several months.

John William Draper was born at St. Helen's, England, May 5th, 1811. His early education was received at the Wesleyan School at Woodhouse Grove, and subsequently from private teachers. At a still later period he made especial study of Chemistry, Natural Philosophy and the higher Mathematics, taking high rank in the knowledge of these sciences.

In 1833 he came to the United States, intending to make it his permanent home. Here he seems to have had his attention for the first time turned to the profession of Medicine, for he entered the Medical Department of the University of Pennsylvania and graduated in 1836. He never practised medicine, however; probably he never had a patient. A few months after receiving his diploma, he was appointed Professor of Chemistry, Physiology and Natural Philosophy in Hampden-Sidney, College, in Virginia. He occupied this position for about three years, publishing during that period several important essays on chemical and physiological subjects. Some of these appeared in the *American Journal of Medical Sciences*, but the greater number in the *London, Edinburgh and Dublin Philosophical Magazine*.

In 1839 he resigned his professorship at Hampden-Sidney College, to accept that of Chemistry and Natural Philosophy in the newly inaugurated University of the City of New York. In 1841 on the origination of the Medical Department of the University, of which he was one of the founders, he was appointed Professor of Chemistry. In 1850 Physiology was combined with Chemistry and he held the joint chair. The union was continued till 1865, when Dr. Draper gave up the teaching of Chemistry in the Medical Department, continuing, however, to lecture on Physiology. In 1867 he resigned this professorship also, retaining, however, the Presidency of the Medical Faculty, which he had held from 1850. In 1873 he severed his connection altogether with the Medical Department, but continued to the day of his death to hold his professorship in the Department of Arts.

Dr. Draper was, early in his career, an experimenter in various departments of Natural Science. In 1840 he described the figures which are formed when coins are laid on polished glass and which are made visible by exposure to the action of a vapor. About the same time he began to interest himself in the discoveries being made by Daguerre and was the first to photograph the human face.

The chemical action of light was a favorite study with him. In 1844 he published his work on the "Forces which produced the Organization of Plants," in which he showed that the yellow ray of the solar spectrum is the most powerful in its influence over vegetation. One of the most important contributions made by him to science is that in which he demonstrates that all solid substances become incandescent at about the temperature of 977° F.

Dr. Draper did not confine his studies to the Natural Sciences strictly so-called. He was ambitious of distinction as a historian. His basis was, that nations are subject to the same laws as individuals and that in their migrations and stages of development they have been acted upon by purely physical causes. We are inclined to think that he carried his views in this respect, too far, and that he disregarded the undoubted influence of intellectual and emotional factors as creators and modifiers of history.

Dr. Draper's contributions to Scientific Periodicals and the Transactions of Medical Societies have been very numerous. One paper only was presented to the American Philosophical Society, and this was May 27th, 1843. He was elected a member of the Society January 19th, 1844, and consequently this memoir was submitted before he joined us: its title is, "On the Decomposition of Carbonic Acid and the Alkaline Carbonates by the Light of the Sun." It is published in Vol. III of the Proceedings.

His published volumes are as follows:

"A Treatise on the Forces which produce the Organization of Plants," 1844.

"A Text-Book of Chemistry," 1846.

"A Text-Book of Natural Philosophy," 1847.

"A Treatise of Human Physiology," 1856.

"History of the Intellectual Development of Europe," 1862.

"Thoughts on the Future Civil Policy of America," 1865.

"History of the American Civil War," 1867–70.

"History of the Conflict between Religion and Science," 1877.

In all these works Dr. Draper showed that he had read extensively and thought deeply. He had great facility for expressing himself with clearness and directness and hence for impressing his views upon others. Nevertheless it must be confessed, that his chief claim for distinction will rest upon his labors in Chemistry and Natural Philosophy. His "Treatise on Human Physiology" is in many respects fanciful and speculative, and theories are promulgated as well-founded which have no support from facts. His historical works are characterized by an entire absence of references to the sources of his information, and therefore they lost much of the value which they would otherwise possess for students.

In 1876 he was awarded the Rumford Medal by the American Academy of Arts and Sciences, for his researches on Radiant Energy. In 1881 he was elected one of the twelve honorary members of the Physical Society of London.

Stated Meeting, March 17, 1882.

Present, 10 members.

President, Mr. FRALEY, in the Chair.

The death of Dr. Joseph Pancoast, March 7th, 1882, æt. 77, was announced by Mr. Eli K. Price. On motion Prof. Samuel D. Gross was requested to prepare an obituary notice.

Letters of acknowledgment were received from the Astronomische Gesellschaft, Leipsig (108), Free Public Library, New Bedford (109), and the Numismatic and Antiquarian Society of Philadelphia (109).

A letter was received from the Kaiserliche Universitäts-und Landes-Bibliothek, Strassburg, dated Feb. 16, 1882. The matter was referred to the Secretaries with power to act.

Donations for the Library were received from F. Sandberger; Zoologische Anzeiger, Leipsig; R. Accademia dei Lincei, Rome; Academie Royale, Bruxelles; Société de Géographie, and Revue Politique, Paris; Société de Géographie Commerciale, Bordeaux; Royal Astronomical Society and Nature, London; M. E. Wadsworth, Boston; Essex Institute, Salem; Journal of Banking Law; Pennsylvania Historical Society, Franklin Institute, Journal of Pharmacy, The American, Philadelphia; New Jersey State Geological Survey; American Chemical Journal; U. S. Signal Service Bureau, Washington; Historical Society of Wisconsin; Mercantile Library Association, San Francisco; Illinois State Museum of Natural History, and Prof. Lesquereaux, Columbus.

The President reported that he had requested Dr. Ruschenberger to prepare an obituary notice of Dr. Bridges, and Dr. Rothrock one of Thos. P. James, and that they had accepted the appointment.

Prof. Sadtler read a paper by Prof. Edgar F. Smith, and N. Wiley Thomas, on Corundum and Wavellite from localities as yet unknown to mineralogists, about six or eight miles from Allentown, Pa.

Mr. Phillips made a communication in reference to the

progress of the New Dictionary of the English Language, now progressing under the auspices of the Philological Society.

Pending nominations Nos. 835, 951 to 956, and new nominations Nos. 957 and 958 were read.

The resignation of the Rev. Samuel Longfellow, of Germantown, Pa., was presented to the Society, and on motion accepted.

And the meeting was adjourned.

Corundum and Wavellite. By Edgar F. Smith and N. Wiley Thomas.

(*Read before the American Philosophical Society, March 17, 1882.*)

Specimens of these minerals from localities, as yet perhaps unknown to mineralogists, came under our examination some time ago, and thinking that a description of them might not be without some interest to specialists, we submit the following:

1. Early in January last, a piece of what was once a large hexagonal prism of corundum terminated by pyramids, was handed us. The specimen we received was an end piece exhibiting a perfect hexagonal form, with pyramidal ending, and on the broken surface of the crystal, the color observed was blue. The weight of this specimen is five pounds. The original complete crystal measured eight inches in length, and the diameter over the secondary axes is about four and one half inches. On the exterior surface are observable here and there, magnetite crystals and these were the cause of the destruction of the original crystal soon after it had been ploughed up. The farmer thinking he had made a valuable discovery and curious to know the appearance of the inside, broke the crystal into several pieces, one of these coming into our possession, after it had been carried about to various parties, for inspection and determination. Only very slight indications of any alteration are apparent on the exterior of the crystal. Soon after getting the above, we received another crystal —a double pyramid—about five and one-half inches long and weighing over five pounds. Since the reception of the preceding, we obtained several cigar boxes full of smaller, well-defined crystals. All of our specimens were found near Shimersville, Lehigh Co., Pa., and were thrown out while plowing. The district over which these crystals were scattered, and have been noticed, is rather extensive and is already under lease, and "prospecting" for larger quantities has been commenced. Quite a number of medium sized crystals were sent to the Weissport Emery Works,

there tested and declared excellent for technical purposes. We reserve our analyses of the above for a future communication.

2. The specimens of Wavellite are from the neighborhood of Macungie, Lehigh Co., Pa. They present radiating nodules on limonite; their color is white. These crystals were considered to be calamine, and on this account we experienced some difficulty in ascertaining the locality. Indeed, we were obliged to show qualitative proof of the absence of zinc to the parties interested, before being made acquainted with the history of the specimens. Our analyses were made of some of the well-defined crystals. The method of analysis pursued, was that described by Dr. F. A. Genth, in *Am. Journal of Science, etc.*, II. Vol. 23, p. 423.

Analysis.

Al_2O_3	36.66 %
P_2O_5	34.14
H_2O	28.32
Fl	*trace*
Limonite	0.60
	99.72

Chemical Laboratory of Muhlenberg College, Allentown, Pa., March 3, 1882.

Stated Meeting, April 7, 1882.

Present, 12 members.

President, Mr. FRALEY, in the Chair.

Letters accepting membership were received from S. S. Lewis, Corpus Christi College, Feb. 4; and from Wm. Blades, Abchurch Lane 23, London, Feb. 18, 1882.

Letters of acknowledgment were received from the K. K. Central-Anstalt für Meteorologie, Wien (108); Verein für Erdkunde, Dresden (105–106); Franklin Institute, Philadelphia (Catalogue Part I.); Prof. Thos. C. Porter, Easton, Pa. (109); West Chester Philosophical Society (109); Mr. Asaph Hall, Washington (109); and the Smithsonian Institution (109).

Letters of envoy were received from the Central Physical Observatory, St. Petersburg, dated Feb. 1882; Prof. F. Reuleaux, Berlin, March 10, 1882; Verein für Erdkunde, Dresden;

U. S. Naval Observatory, Washington; and the Department of State, Washington, April 1, 1882.

Donations for the Library were received from the Academies at St. Petersburg, Berlin, Munich, Rome and Brussels; Prof. Reuleaux, Braunschweig; Herr. Aug. Tischner, and the Zoologischer Anzeiger, Leipsig; Herr. L. Rütimeyer, Zurich; Geographical Societies at Paris and Bordeaux; Baron J. De Baye, Chalon-sur-Marne; Royal Library at the Hague; Flora Batava, Leyden; Royal Astronomical Society, and Nature, London; Mr. M. E. Wadsworth, Boston; American Academy of Arts and Sciences; American Journal, New Haven; Mr. E. A. Barber, Mr. Lorin Blodget, Mr. Henry Phillips, Jr., Dr. Jayne, the Academy of Natural Sciences, Board of Directors of City Trusts, and the Editors of the "American," Philadelphia; Johns Hopkins University, Baltimore; U. S. Fish Commission, U. S. National Museum, U. S. Census Bureau, U. S. A. Department of Engineers, and the U. S. Naval Observatory, Washington, D. C.; The Virginias, Staunton, Va; American Antiquarian, Chicago.

A letter from the Wyoming Geological Society was referred to the Secretaries with power to act.

The death of Solomon W. Roberts, at Atlantic City, March 22, in the 71st year of his age, was announced by Mr. J. S. Price, and Mr. Fraley was requested to prepare an obituary notice of the deceased.

The death of Edouard Desor, at Nice, Feb. 23, in the 71st year of his age, was announced; and Mr. Lesley was appointed to prepare a notice.

The death of Dr. Robert S. Kenderdine, in Philadelphia, March 27, aged 51, was announced by Mr. J. S. Price, and the President was requested to appoint a proper person to prepare an obituary notice of the deceased.

Mr. Ashburner read a paper on "Estimation of Coal Areas and Coal Contents of the Anthracite Fields of Pennsylvania."

Prof. Cope read a paper on a new form of Marsupial Mammal from the Lower Eocene of New Mexico.

Prof. Cope read a paper on Archæsthetism.

Mr. Eli K. Price read the following report as Chairman of the Committee on the Michaux Legacy:—

"The course of lectures in Fairmount Park was successfully delivered by Dr. Rothrock in 1881, according to annexed statement.* The audience was interested and highly respectable; the number varying from two to four hundred.

"I recommend the continuance of the lectures for the present year; and that an appropriation be made of two hundred and eighty dollars ($280) for the lecturer, and fifty dollars ($50) for advertising. The course will be according to annexed schedule in manuscript."†

On motion it was ordered that an appropriation of $330 be made for the above objects, payable out of the Michaux Legacy.

Pending nominations Nos. 935 and 951 to 958 were read, and the meeting was adjourned.

Stated Meeting, April 21, 1882.

Present, 8 members.

President, Mr. FRALEY, in the Chair.

Letters of acknowledgment were received from the Glasgow Philosophical Society (107–108); the Royal Geological Society of Ireland, Dublin (XV, 3; 107–108); and the Franklin Institute, Philadelphia (108–109).

* In 1881, from April 23d to June 18th, on Saturdays at 4 P. M.:—Subjects—1. How and why we study Botany; 2. The Plants we Eat; 3. The Plants we Drink; 4. The Plants we Wear; 5. How we and the Plants Breathe and How we help each other; 6 and 7. Diseases of Plants.

II. From September 10th to October 8th:—8. Strange Marriage among Plants; 9. Forestry in Europe; 10. Want of Forestry in America and its Consequences; 11. How Trees are made; 12. How Plants Travel; 13. Weeds; 14. Botany for Winter.

† In 1882, on Saturdays, at 4 P. M., from April 22d to June 3d. Subjects—1, 2. Plants which have influenced Human History. 3, 4. How Plants are Constructed. 5, 6. How Plants are Organized. 7. Meat-eating Plants.

II. September 9 to October 21.—8. How Vegetation protects the Earth and influences Rain-fall. 9. What the Roots do and how they do it. 10. American Timber and its special value. 11, 12. Sick Plants. 13. Strength and Durability of Timber. 14. The Plants eaten by other Nations.

Letters of envoy were received from the Naturforschende Gesellschaft, Görlitz, dated Nov. 5, 1881; Naturhistorische Gesellschaft, Nürnburg, Nov. 16, 1881; Kgl. Hof-und-Staats-Bibliothek, München, Dec. 27, 1881; Meteorological Office, London, March, 1882; Canada Geological and Natural History Survey, Montreal, April, 1882; Department of the Interior, Washington, April 7, 1882; Louisiana Board of Health, New Orleans, March 30, 1882; and the Public Museum of Buenos Ayres.

Donations for the Library were received from the Academies at St. Petersburg, Copenhagen, Munich, Rome, and Brussels; Observatories at St. Petersburg, and Munich; Geological Society, Berlin; Natural History Societies at Görlitz, Chemnitz, Nuremburg, and St. Gall; Royal Society, Göttingen; Zoological Society, Leipsig; Royal Library, Munich; K. K. Geol. Reichsanstalt, and the Anthropologische Gesellschaft, Vienna; Herr Joachim Barrande, Prag; Musée Guimet, Lyons; Anthropological, and Geographical Societies, Ecole Polytechnique, and Revue Politique, Paris; Revista Euskara, Pamplona; L. G. De Koninck, Liège; Astronomical, Meteorological, Royal Geographical, Geological, and Royal Asiatic Societies, and Society of Arts, London; Geological Survey of India, Calcutta; Glasgow Philosophical Society; Geological and Natural History Survey of Canada; Prof. J. D. Whitney and Prof. Alex. Agassiz, Cambridge; American Antiquarian Society, Worcester; Prof. O. C. Marsh, New Haven; Prof. J. Henry Comstock, Ithaca; Capt. Jas. E. Cole, N. Y.; State Board of Agriculture, Harrisburg; Philadelphia and Reading R. R. Co.; U. S. Fish Commission, U. S. Entomological Commission, U. S. National Museum, and Census Bureau, Washington; Louisiana State Board of Health; National Museum, Mexico; and the Public Museum, Buenos Ayres.

Dr. Gross declined by letter, on account of numerous engagements, his appointment to prepare an obituary notice of Dr. Pancoast.

The death of Charles Robert Darwin, April 20, aged 73, was announced by Dr. Le Conte.

Dr. LeConte said:

In rising to announce the death of Charles Robert Darwin, which occurred on the nineteenth day of April, last, in the seventy-fourth year of his age, I have no intention to give a biographical sketch of his life, or his contributions to science. This labor of love will be performed fully by some of his compatriots, who have had the benefit of the sweet and instructive personal intercourse with him which has failed to be part of our earthly enjoyment. But what I do wish to manifest, as far as the feeble power of my language will permit, is the deep grief which we feel, at the loss of one, who has by his work and his writings, become a dear companion, and a guide in our scientific thought.

For, to no man more than to Darwin, does the present age owe as much, for the gradual reception of the modern method of close observation over the scholastic or *a priori* formulæ, which, up to a brief period, affected all biological investigations. To him, above all men, we owe the recurrence to the old Aryan doctrine of evolution (though in those ancient times promulgated under the guise of inspiration) as preferable, by reasonable demonstration, to the Shemitic views, which have prevailed to within a few years, and are still acceptable to a large number of well-minded but unthinking men. The doctrine of evolution, in its elementary form, means nothing more than that everything that exists has been derived from something that pre-existed; that the former is related to the latter as effect is to cause. And it is most pleasing evidence of the acceptability of this doctrine, that it is now heard from many pulpits in the land, as a strong illustration of the instructions which are thence given.

Therefore, while lamenting the death of Darwin, at a ripe old age, and losing the benefit of his vast store of learning, which could not much longer remain with us, we are grateful that we have lived in a generation in which he was a conspicuous example of the humble and holy men of heart, which other scientific men should endeavor—albeit, with much less capacity—to imitate.

And, finally, we offer to the bereaved family our most heartfelt sympathy in their affliction, and our trust that the well-chosen ancestral alliances will enable the descendants to worthily succeed in attaining the honor and usefulness which characterized our deceased colleague.

The death of John Lenthall, U. S. N., April 11, at Philadelphia, in his 75th year, was announced.

The death of Robert Christison, M. D., of Edinburgh, was reported as having taken place in 1880.

Mr. Chase communicated Photodynamic notes No. V.

Mr. H. C. Lewis described his observations of the aurora of April 19 and 20, proving its connection with the earth by the

apparent motion of the corona eastward at the rate of 15° per hour.

Nominations Nos. 951 to 958 were read and balloted for.

Mr. Fraley reported that he had collected and paid over to the Treasurer the interest on the Michaux Legacy, due April 1, amounting to $133.07.

On scrutiny of the ballot boxes, the following were declared duly elected members of the Society:

951. Charles W. King, Fellow of Trinity College, Cambridge, England.

952. Rev. James W. Robins, D. D., Principal of the Episcopal Academy in Philadelphia.

953. Charles Sprague Sargent, A. B., Cambridge, Mass., Professor of Botany.

954. Franklin B. Hough, M. D., of Lowville, N. Y.

955. Stephen P. Sharples, of Boston, Mass., late Asst. Prof. Chem. Harvard College.

956. Charles Edward Rawlins, Esq., of Rock Mount Rainhill, Liverpool, England.

957. George de B. Keim, Esq., of Philadelphia.

958. Hamilton Andrews Hill, Esq., of Boston, Secretary of the National Board of Trade.

And the meeting was adjourned.

Photodynamic Notes, V. By Pliny Earle Chase, LL.D.

(*Read before the American Philosophical Society, April 21st, 1882.*)

158. *Synchronous Areas.*

Kepler's second law is grounded upon principles which must modify rotation and subsidence, so as to introduce harmonic tendencies among the synchronous areas which are described by different bodies, under the controlling activity of a common centre, as well as in the virtual areas which represent the reaction of the subordinate masses upon the centre of gravity of the system. In orbits of small eccentricity, the instantaneous area of a particle is nearly proportional to the square root of its mean radius vector. If we take $r = (\frac{1}{2})^3 = .125$, as a harmonic divisor, the first of these tendencies is shown by the principal planets, as may be seen in the following table:

Harmonic Areas.		Synchronous Areas.		Difference.
$5\,r$	.625	Mercury	.6222	+ .0028
$7\,r$	.875	Venus,	.8505	+ .0245
$8\,r$	1.000	Earth,	1.0000	.0000
$10\,r$	1.250	Mars,	1.2344	+ .0156
$18\,r$	2.250	Jupiter,	2.2810	— .0310
$25\,r$	3.125	Saturn,	3.0885	+ .0365
$35\,r$	4.375	Uranus,	4.3799	— .0049
$44\,r$	5.500	Neptune,	5.4803	+ .0197

All the differences are within the limits of probable error, .03125, except Saturn's. Jupiter's area is nearly $\frac{3}{4}$ of Saturn's, and the combined masses of these two planets is so great as partially to override the simple tendencies of subsidence towards the chief centres of condensation and nucleation, Earth and Sun.

The synchronous areas of Mercury and Mars, the outliers of the dense belt, are nearly in the ratio 1 : 2; Venus and Earth, 7 : 8; Uranus and Neptune, 4 : 5. The difference is less than $\frac{1}{16}$ of the probable error in the first of these comparisons; less than $\frac{1}{2}$ of the probable error in the second; less than $\frac{1}{10\,0}$ of the probable error in the third; the "probable error," in each case, being $\frac{1}{4}$ of the common divisor, or the deviation which would be admissible without weakening the evidence of harmonic tendency in a *vera causa*.

159. *Virtual Areas.*

The virtual areas of synchronous reaction, or the instantaneous areas which a particle, at Sun's mean distance, would describe about the principal planets if it were not restrained by stronger influences, vary as $\sqrt{m\,r}$. *Vis viva* may be represented by orbital areas, as well as by distances of projection against uniform resistance, therefore we may add a third law to

Laplace's two laws of constant sums, viz :—*The sum of all the instantaneous virtual areas in a system will always remain invariable.*

From Alexander's harmony (Note 156, p. 605) it follows, that the ratio between the virtual areas of Jupiter and Saturn is nearly the reciprocal of the ratio of their direct areas. The harmonic influence of the repeated nodal action of this ratio, upon subordinate planetary aggregation, is shown in the following table :

Harmonic Areas.		Virtual Areas.		Difference.
a	40.256	Jupiter,	40.587	— .331
$\beta = \frac{3}{4}\, a$	30.192	Saturn,	30.063	+ .129
$\gamma = \frac{3}{4}\, \beta$	22.644	Neptune,	22.675	— .031
$\delta = \frac{3}{4}\, \gamma$	16.983	Uranus,	16.782	+ .201
ε	1.000	Earth,	1.000	.000
$\zeta = \frac{3}{4}\, \varepsilon$	.750	Venus,	.749	+ .001
$\eta = \frac{2}{5}\, \varepsilon$	.400	Mars,	.404	— .004

The greatest proportionate difference is that of Uranus, $1\frac{1}{2}$ per cent. The harmonic change from the outer to the inner belt of planets, $\delta \div \varepsilon = 16.983$, represents the orbital retardation at the chief centre of condensation, Earth. If Earth were rotating with the speed which it would have if Laplace's limit coincided with its equatorial surface, its time of rotation would be $2\pi\sqrt{\frac{r}{g}} = 5073.6$ seconds ; $86164.1 \div 5073.6 = 16.983$. The synchronous virtual area of Mars differs by less than $4\frac{1}{2}$ per cent. from $\frac{3}{4}$ of $\frac{3}{4}\, \zeta$. This is less than 18 per cent. of the probable error.

160. *Laplace's First Law of Stability.*

The first of the two laws in which the author of *Mécanique Céleste* embodied his discoveries in relation to the stability of the solar system, is thus stated ; "If the mass of each planet be multiplied by the product of the square of the eccentricity and square root of the mean distance, the sum of all these products will always retain the same magnitude." By combining the first and third of these factors, $m\sqrt{r}$, we get the quotient of mass by orbital velocity, together with the following suggestions of nodal influence:

	$m\sqrt{r}$		Semi-axes major.	
Jupiter	722.19 =	5.184^{4}	γ_5	5.203
Saturn,	279.46 =	$9.695^{\frac{5}{2}}$	γ_8	9.539
Neptune,	93.82 =	$30.146^{\frac{3}{4}}$	γ_9	30.037
Earth,	1.00		γ_3	1.000

Jupiter's exponent represents the variable ratio of subsidence-acceleration to orbital velocity ; Saturn's the product of orbital time by mean distance; Neptune's, the variable ratio of Laplace's limit to nucleal radius.

161. *Orbital Momentum.*

The division of $m\sqrt{r}$ by r gives the product of mass by orbital velocity, or orbital momentum, together with the following suggestions of photodynamic or nebular activity :

	$m \div \sqrt{r}$		Cardinal Radii.	
Jupiter,	$138.81 = 5.178^3$		γ_5	5.203
Saturn,	$30.68 = 9.800^{\frac{3}{2}}$		β_6	10.000
Uranus,	$3.35 = 20.567^{\frac{2}{3}}$		α_7	20.679
Neptune,	$3.12 = 30.483^{\frac{1}{2}}$		α_8	30.470
Earth,	1.00		γ_3	1.000

Jupiter's exponent represents the ratio of its photodynamic orbital volume to that of Earth ; Saturn's, the ratio of orbital times ; Uranus's the influence of mean rotary *vis viva* in an elastic medium ; Neptune's the influence of a centre of linear oscillation in an elastic medium.

162. *Coefficient of Solar Torsion.*

In applying the oscillatory equation, $t = \pi\sqrt{\frac{l}{g}}$, at the centre of gravity of a stellar system, let t represent the duration of an oscillation or half-rotation, g the acceleration of gravity at the stellar equatorial surface, $\pi^2\, l$ the stellar modulus of light or the height of a homogeneous æthereal atmosphere which would propagate undulations with the velocity of light. Then, if the stellar rotary oscillation is due to the reaction of cosmical inertia against æthereal influence, gt is equivalent to the velocity of light, v_λ.

In Coulomb's formula of torsional elasticity, $f = \frac{\pi^2\, a^2\, W}{2\, gt^2}$, W represents a weight suspended by a wire, a the coefficient of the radius of torsion, f the coefficient of torsion for the extended wire, g gravitating acceleration, t time of oscillation when the force of torsion is removed. Applying this formula to solar rotation, we have

$$f = \frac{m}{2} = \frac{W}{2} \cdot \frac{\pi^2\, a^2\, r_\circ}{gt^2} ; \quad \therefore\ \pi^2\, a^2\, r_\circ = gt^2 = \pi^2\, l.$$

But gt is the velocity which would be communicated by gravity, at Sun's surface, in one oscillation of half-rotation, or the velocity of light ; gt^2 is the modulus of light at Sun's surface ; $a^2\, r_\circ$ is the theoretical length of a pendulum, at Sun's surface, which would oscillate once in each half-rotation ; $a\, r_\circ$ is the length of an equatorial radius rotating with Sun and having the superficial orbital velocity, $\sqrt{gr}$, at its remote extremity. These are the same results as have been already derived from simple gravitating and radiodynamic considerations, Notes 17, 48, 100, etc. Their statement in this form may be satisfactory to some readers who have not followed the foregoing investigations through all their details.

163. *Harmonic Categories.*

The simple discovery of so many harmonies, in all departments of physical science, would be interesting, even if it were accidental or wholly empirical. The fact that the discovery has sprung from systematic investigations, under the guidance of well-known laws, adds much to its importance. The following results seem to be especially important, and somewhat typical.

1. The equality of gt, in the solar oscillations of half-rotation, to the *velocity of light.* Notes 17, 162, etc.

2. The relations of mass and *vis viva* which satisfy cosmical tendencies to nodality, subsidence, oscillation and orbital revolution. Notes 5, 23, 79, 91, 156, 158–61.

3. The far-reaching evidence of elastic influence which establishes measurable progressive relations between the solar system and the fixed stars. Notes 46, 111–5, 130–2, 155.

4. The simplicity of the relations between elastic and cosmical *vis viva*, which furnish data for approximate estimates of Sun's mass and distance by means of barometric fluctuations. Notes 104–5.

5. The relations of magnetic and cosmical *vis viva*, together with the evidence which they furnish of the dependence of solar and lunar magnetic disturbances upon thermal and tidal influences. Notes 2, 116–22, 125–6.

6. The curiously symmetric harmony in Mars and its satellite-system. Note 28.

7. The varied harmonies of spectral lines, together with the relations of planetary positions to luminous nodes. Notes 36–45, 109, 141–2, 144–53, 157.

8. The confirmations of predictions which were founded upon evidences of the influence of harmonic laws. Notes 33, 133, etc.

9. The interchangeable convertibility of physical units. Notes 90, 96.

10. Atomic phyllotaxy. Notes 135–9, 143. Although Gerber's divisors were found empirically, they represent natural elementary groups. His utter want of suspicion that they had any physical meaning makes them much more important than they would have been if his investigations had been biased by a preconceived hypothesis. The kinetic theory of gases necessitates harmonic action, and the tendency to division in extreme and mean ratio leads to one of the most simple kinds of harmony. There is no necessary inconsistency between the doctrine of atomic phyllotaxy and Prout's hypothesis.

164. *Mercury's Virtual Area.*

The fundamental ratio of successive virtual areas, $\frac{3}{4}$, represents the ratio of the locus of linear centre of gravity of a simple pendulum to the locus of its centre of oscillation, as well as the exponential ratio of nucleation to limitation in an elastic medium. The intermediate step between the harmonic areas for Mars and Venus, Note 159, may, perhaps, be distributed,

partly among the asteroids, partly in satisfying special requirements of the dense belt, and partly in the variations of æthereal *vis viva*. The mass of Mercury is so imperfectly known that it is unsafe to put much trust in the accuracy of any merely harmonic indications of its value, but its virtual area is unquestionably of the same order of magnitude as $(\frac{3}{4})^3$ of that of Mars, or $\frac{729}{4096}$ of that of Earth. This would give, for an approximate estimate of the quotient of Sun's mass by that of Mercury, 4054440. The two intermediate steps may, perhaps, be partly absorbed by the intra-Mercurial harmonic nodes and the meteoroids of the zodiacal light.

165. *Relative Masses of Neptune and Mars.*

An intermediate step between the virtual areas (Note 159) and the nodal masses (Note 156), is indicated by the ratio between the masses at the outer limits of the supra-asteroidal and the intra-asteroidal belts. The quotient of the square of Neptune's harmonic virtual area, 22.644^2, by its harmonic radius, 30.036*, is 17.071; the quotient of the squared area of Mars, $(\frac{3}{4})^6$, by its harmonic radius, 1.669, is .10664; the ratio of the masses and the mass-ratio of Sun to Mars are approximately shown in the following proportions:

$$m_8 : m_4 :: 17.071 : .10664 :: 160.09 : 1$$
$$m_0 : m_4 :: (160.09 \times 19380 = 3102544) : 1$$

166. *Various Harmonic Indications and Tests.*

If κ represents Earth's limiting nucleal radius (Note 159), the corresponding atmospheric radius would be $\kappa^{\frac{4}{3}} = 43.653$. Herschel's locus of incipient subsidence, in the controlling two-planet belt, or Saturn's secular aphelion, is 1.0843289 times the outer limiting locus of the belt (Stockwell, *Smithson. Contrib.*, 232, p. 38); $\kappa^{\frac{4}{3}} \div 1.0843289 = 40.258$, which is, with close approximation, the ratio of the instantaneous virtual area at the inner locus of the controlling belt, to the corresponding area at the chief centre of condensation. The tendency of exponents, in elastic media, to become coefficients of elastic *vis viva*, is shown in Note 159. If we use the symmetrical harmonic areas for Mars and Mercury, the percentages of difference between the harmonic and virtual areas are, respectively, $\frac{5}{6}$ of .01, $\frac{4}{7}$ of .01, $\frac{1}{7}$ of .01, $\frac{6}{8}$ of .01, $\frac{1}{7}$ of .01, .045, .099. In testing the combined harmonic influences of a *vera causa* which is subject to internal perturbations, there is room for a possible deviation of 50 per cent. and a probable deviation of 25 per cent. The combined probability that the approximations in Note 159 are owing to æthereal influence is, therefore, $30 \times \frac{175}{1} \times 175 \times \frac{175}{1} \times 175 \times \frac{50}{9} \times \frac{250}{99} = 15664091727$:

The following points of symmetry and alternation may be noted in the nodal mass-factors of the two outer planets, Note 156:

1. The tendency to equality of mean orbital *vis viva* in Earth, Uranus and Neptune, as indicated by the factors γ_3, γ_7 and γ_8.

* Proc. Am. Ph. Soc., xiii, 239.

2. The nodal modification of Neptune's mass by Earth's secular aphelion, and of the mass of Uranus by Earth's secular perihelion.

3. The nodal modification of Neptune's mass by its own mean perihelion, and of the mass of Uranus by its own mean aphelion.

4. The modification of Uranus by Jupiter, and the corresponding modification of Neptune by Uranus.

167. *Earth's Modulus of Rotation and Jupiter's Eccentricity.*

Let g_β represent the sum of the gravitating accelerations of Sun and Earth at Earth's equatorial surface; t, time of Earth's rotary oscillation ($\frac{1}{2}$ sidereal day); ρ_o, Sun's equatorial semi-diameter; r_3, Earth's semi-diameter; ρ_a, mean projection of centre of gravity of Sun and Jupiter from ρ_o; $\rho_a \div \rho_o$, Jupiter's maximum secular eccentricity; ρ_3, Earth's semi-axis major; $g_\beta t^2$, Earth's modulus of rotation. Then

$$g_\beta t^2 : \rho_3 :: \rho_a : \rho_o.$$

The photodynamic or oscillatory values of Sun's mass and distance, Note 91, give for Sun's gravitating acceleration of Earth $\frac{m_o}{m_3}\left(\frac{r_3}{\rho_3}\right)^2 = 331776 \times (3962.8 \div 92785700)^2 = .000605184$ of Earth's equatorial gravitating acceleration. If we adopt Everett's value for g, $g_\beta t^2 = 1.000605184 \times 32.091 \times 43082^2 \div 5280 = 5643840$ miles; $\rho_a \div \rho_o = .0608265$. Stockwell's value (*Smith. Cont.*, 232, p. 38), is .0608274.

168. *Axis of Central Subsidence and Rupture.*

The influence of the interstellar photodynamic paraboloid is shown in the boundaries of the belt of greatest condensation. The locus of incipient rupture, Mercury's secular perihelion, is about $\frac{1}{6}$ of the locus of incipient subsidence, secular aphelion of Mars. Stockwell's values for the two loci are .2974008 and 1.736478. This gives for the major axis of the several incipient ellipses, described by the subsiding particles from the outer portion of the belt, $.2974008 + 1.736478 = 2.0338788$. Let g_o, g_3 represent equatorial superficial gravitating acceleration of Sun, Earth, respectively; m_5, m_3, masses of Jupiter, Earth; t_a, time of Jupiter's orbital revolution; t_β, time of Earth's rotation; ρ_3, Earth's semi-axis major; ρ_a, asteroidal radius equivalent to major axis of incipient ellipses of dense belt. Then

$$\frac{t_a^2}{t_\beta} \times \frac{m_3}{m_5} \times \frac{\rho_a}{\rho_3} = \frac{g_o}{g_3}$$

$$4332.58482 \div 316.617 \times 2.0338788 = \frac{g_o}{g_3} = 27.8316$$

$$\frac{m_o}{m_3} \times \frac{g_3}{g_o} = \left(\frac{r_o}{r_3}\right)^2$$

$$331776 \div 27.8316 = 11920.8$$

$$\frac{r_0}{r_3} = \sqrt{11920.8} = 109.183$$
$$r_0 = 109.183 \times 3962.8 = 432669 \text{ miles.}$$
$$\rho_3 \div r_0 = 92785700 \div 432669 = 214.45$$

These results may be compared with those which were given in Notes 91, 113 and 156, the extreme range of difference being less than $\frac{1}{10}$ of one per cent.

169. *Earth's Incipient Subsidence.*

If the various relations which are shown in the foregoing note are due to Earth's atmospheric and nucleal subsidence from the centre of the dense belt $\left(\frac{\rho_n}{2} = 1.0169394\right)$, its secular aphelion should be $\left(\frac{\rho_n}{2}\right)^4 = 1.0695$. Stockwell gives (*op cit.*, p. 38) 1.0677352, upon the assumption that $\frac{m_0}{m_3} = 368689$. On page xi of his Introduction he gives 1.0693888; on page xvii he gives a series of values which yield, by interpolation, 1.0691 for the photodynamic mass-ratio, $\frac{m_0}{m_3} = 331776$.

170. *Progression of Fundamental Atomicities.*

Thomas Bailey, (*Phil. Mag.*, Jan. 1882, p. 35), gives a series of atomic weights corresponding to minimum volumes, which are members of the geometric series a, ab, ab^2, ab^3, ab^4, the value of b being $\frac{1}{6}$ of a and the value of a being 10. This suggests an atomic parabolic motion, like that in the photodynamic or interstellar paraboloid, in which $\xi = \frac{1}{6}$. We may also notice that 6 is the product of the two phyllotactic numbers, 2 and 3.

171. *Perissad Phyllotaxy.*

The indications of phyllotactic tendency in various departments of physics, have induced me to test Gerber's groupings of chemical atoms by methods which seem to me to be perfectly legitimate. In order to remove all effects of personal equation or bias, as well as of accidental or empirical coincidence, I adopt Clarke's recalculation of atomic weights (*Phil. Mag.* [5] 12, 109–10), and my strictly phyllotactic divisors (Note 136), instead of Gerber's empirical divisors. In view of the *a priori* probability of tendency to division in extreme and mean ratio, I assume that the ratio of probability to improbability, in each instance, is equivalent to at least $\frac{1}{4}\ D : (T-O)$; D being the phyllotactic divisor, T the theoretical atomic weight or nearest exact multiple of D, and O the observed atomic weight taken from Clarke's table. I have added Rb and Tl to Gerber's list of monatomic elements, and Bo to his trivalent list.

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Monatomic Group; $D_1 = .768$.

		T.	O.	T-O.	Probability.
Li	9 D_1	6.912	7.007	.095	192 : 95
Na	30 D_1	23.040	22.998	.042	192 : 42
K	51 D_1	39.168	39.019	.149	192 : 149
Cs	173 D_1	132.864	132.583	.281	192 : 281
Fl	25 D_1	19.200	18.984	.216	192 : 216
Cl	46 D_1	35.328	35.370	.042	192 : 42
Br	104 D_1	79.872	79.768	.104	192 : 104
I	165 D_1	126.720	126.557	.163	192 : 163
Ag	140 D_1	107.520	107.675	.155	192 : 155
Rb	111 D_1	85.248	85.251	.003	192 : 3
Tl	265 D_1	203.520	203.715	.195	192 : 195

Three of the elements, Cs, Fl and Tl, indicate a probability that the phyllotactic approximation may be merely accidental. The aggregate probability that the combining equivalents of the monatomic elements are modified by phyllotactic tendencies, or the product of all the separate probabilities, is more than 5610 times as great as the probability that the approximations are accidental.

Tricalent Group; $D_3 = 1.559$.

		T.	O.	T-O.	Probability.
N	9 D_3	14.031	14.021	.010	389.75 : 10
P	20 D_3	31.180	30.958	.222	389.75 : 222
As	48 D_3	74.832	74.918	.086	389.75 : 86
Sb	77 D_3	120.043	119.955	.088	389.75 : 88
Bi	133 D_3	207.347	207.523	.176	389.75 : 176
Au	126 D_3	196.434	196.155	.279	389.75 : 279
Bo	7 D_3	10.913	10.941	.028	389.75 : 28

All the indications in this group are in favor of phyllotactic influences, the aggregate ratio of probabilities being more than 108426 : 1. Multiplying this by the monatomic ratio we get, for the aggregate perissad ratio, $>$ 608375000 : 1.

172. *Artiad Phyllotaxy.*

Di- or Tetratomic Group; $D_2 = 1.996$.

		T.	O.	T-O.	Probability.
O	8 D_2	15.968	15.963	.005	499 : 5
S	16 D_2	31.936	31.984	.048	499 : 48
Se	40 D_2	79.840	78.797	1.043	499 : 1043
Te	64 D_2	127.744	127.960	.216	499 . 216
Mg	12 D_2	23.952	23.959	.007	499 : 7
Ca	20 D_2	39.920	39.990	.070	499 : 70
Sr	44 D_2	87.824	87.374	.450	499 : 450
Ba	69 D_2	137.724	136.763	.961	499 : 961
C	6 D_2	11.976	11.974	.002	499 : 2

		T.	O.	T-O.	Probability.
Si	14 D_2	27.944	28.195	.251	499 : 251
Ti	25 D_2	49.900	49.846	.054	499 : 54
Zr	45 D_2	89.820	89.367	.453	499 : 453
Sn	59 D_2	117.764	117.698	.066	499 : 66
Hg	100 D_2	199.600	199.712	.112	499 : 112
Mo	48 D_2	95.808	95.527	.281	499 : 281
W	92 D_2	183.632	183.610	.022	499 : 22
U	60 D_2	119.760	119.241	.519	499 : 519

Two of these elements, Se and U, give adverse indications; the aggregate ratio of favorable to adverse probabilities is more than 17173770000000 : 1. I have taken $\frac{1}{2}$ of Clarke's estimate for U, in order to compare it with Gerber's assumed atomicity.

Supplementary Artiad Group.

Barker, in *Johnson's Cyclopædia*, gives other artiad elements which Gerber places in his group of metals. In order to complete the comparisons which are based upon valency they are inserted here:

		T.	O.	T-O.	Probability.
Gl	7 D_2	13.972	13.695	.277	499 : 277
Al	14 D_2	27.944	27.009	.935	499 : 935
In	57 D_2	113.772	113.398	.374	499 : 374
Zn	33 D_2	65.868	64.905	.963	499 : 963
Cd	56 D_2	111.776	111.770	.006	499 : 6
Cu	32 D_2	63.872	63.173	.699	499 : 699
Pb	103 D_2	205.588	206.471	.883	499 : 883
Pd	53 D_2	105.788	105.737	.051	499 : 51
Pt	97 D_2	193.612	194.415	.803	499 : 803
Yt	45 D_2	89.820	89.816	.004	499 : 4
Ce	70 D_2	139.720	140.424	.704	499 : 704
La	69 D_2	137.724	138.526	.802	499 : 802
Di	72 D_2	143.712	144.573	.861	499 : 861
Er	83 D_2	165.668	165.891	.223	499 : 223
Th	117 D_2	233.532	233.414	.118	499 : 118
Cr	26 D_2	51.896	52.009	.113	499 : 113
Fe	28 D_2	55.888	55.913	.025	499 : 25
Mn	27 D_2	53.892	53.906	.014	499 : 14
Ni	29 D_2	57.884	57.928	.044	499 : 44
Co	30 D_2	59.880	58.887	.993	499 : 993
Ru	52 D_2	103.792	104.217	.425	499 : 425
Rh	52 D_2	103.792	104.055	.263	499 : 263
Ir	97 D_2	193.612	192.651	.961	499 : 961
Os	99 D_2	197.604	198.494	.890	499 : 890

The first sub-group, Glucinum to Thorium, inclusive, consists of dyads

and tetrads, and gives 40911 : 1 for the combined ratio of probabilities. The other sub-group is hexad, giving the aggregate ratio 11611 : 1. The total aggregate ratio of the artiad elements is more than $81585(10)^{17}$: 1.

173. *Metallic Phyllotaxy.* $D_4 = 1.247$.

		T.	O.	T-O.	Probability.
Gl	11 D_4	13.717	13.972	.255	311.75 : 255
Al	22 D_4	27.434	27.009	.425	311.75 : 425
Sc	35 D_4	43.645	43.980	.335	311.75 : 335
Cr	42 D_4	52.374	52.009	.365	311.75 : 365
Fe	45 D_4	56.115	55.913	.202	311.75 : 202
Ga	55 D_4	68.585	68.854	.269	311.75 : 269
In	91 D_4	113.477	113.398	.079	311.75 : 79
Zn	52 D_4	64.844	64.905	.061	311.75 : 61
Cd	90 D_4	112.230	111.770	.460	311.75 : 460
Mn	43 D_4	53.621	53.906	.285	311.75 : 285
Ni	46 D_4	57.362	57.928	.566	311.75 : 566
Co	47 D_4	58.609	58.887	.278	311.75 : 278
Cu	51 D_4	63.597	63.173	.424	311.75 : 424
Pb	166 D_4	207.002	206.471	.531	311.75 : 531
Tl	163 D_4	203.261	203.715	.454	311.75 : 454
Rb	68 D_4	84.796	85.251	.455	311.75 : 455
Ru	84 D_4	104.748	104.217	.531	311.75 : 531
Rh	83 D_4	103.501	104.055	.554	311.75 : 554
Pd	85 D_4	105.995	105.737	.258	311.75 : 258
Ir	154 D_4	192.038	192.651	.613	311.75 : 613
Pt	156 D_4	194.532	194.415	.117	311.75 : 117
Os	159 D_4	198.273	198.494	.221	311.75 : 221
Yt	72 D_4	89.784	89.816	.032	311.75 : 32
Ce	113 D_4	140.911	140.424	.487	311.75 : 487
La	111 D_4	138.417	138.526	.109	311.75 : 109
Di	116 D_4	144.632	144.573	.079	311.75 : 79
Er	133 D_4	165.851	165.891	.040	311.75 : 40
Th	187 D_4	233.189	233.414	.225	311.75 : 225

The aggregate ratio is 1386.8 : 1, the mean ratio for a single comparison being somewhat less than 4 : 3. The indication of phyllotactic tendency is, therefore, comparatively slight, and far less satisfactory than in the grouping according to valency.

174. *General Test of Atomic Phyllotaxy.*

Computors who are accustomed to calculations of probable error, and who have not given any special attention to the harmonic influences of æthereal vibrations, may, perhaps, question the propriety of making any allowance for an *a priori* probability of division in extreme and mean ratio. For the satisfaction of all doubts upon this point it may be well to apply

some test which will be rigid enough to fulfill the broadest requirements of mathematical likelihood. If we substitute $\frac{3}{16}$ D, for $\frac{1}{4}$ D, in the ratio of probability to improbability, we provide for requirements of linear oscillation, orbital motion and gravitating tendency. In such limited ranges of comparison as are possible for the chemical elements, most mathematicians would, perhaps, be satisfied with this substitution. All doubt should be removed by introducing the coefficient of probable error, .674489, and using $.674489 \times \frac{1}{4}\ \mathrm{D} = .168622\ \mathrm{D}$. If we let n represent the number of terms in a given group, the ratios of probability, which have been found in Notes 171–3, should be multiplied by $.674489^n$, in order to give results which are entirely independent of any *a priori* assumption. We then find

For the monatomic	group,	Note	171	73.75 : 1
" trivalent	"	"	171	6885.88 : 1
" di- or tetratomic	"	"	172	21253910000.00 : 1
" supp'y artiad	"	"	172	37337.33 : 1
" aggregate valency				$403(10)^{18}$: 1
" metallic group, Note 173				1 : 44.33

The mean ratios, for single representatives of the several groups, are the following :

For the monatomic group	1.478 : 1
" trivalent "	3.534 : 1
" 1st artiad "	4.050 : 1
" 2d " "	1.550 : 1
" aggregate valency	2.235 : 1
" metallic group	1 : 1.145

The uniform character of the phyllotactic indications, in the groupings which are based upon similitudes of chemical affinity, is very satisfactory. To all who are willing to attach weight to *a priori* considerations, the following statement of mean ratios may be acceptable :

For the monatomic	group,	Note	171	2.192 : 1
" trivalent	"	"	171	5.223 : 1
" 1st artiad	"	"	172	6.005 : 1
" 2d "	"	"	172	2.299 : 1
" aggregate valency				3.313 : 1
" metallic group,		"	173	1.295 : 1
" perissads				3.076 : 1
" artiads				3.423 : 1
" hydrogen unit				2.084 : 1

The last result was quite unexpected. It was obtained by assuming .250 as a probable mean difference from exact multiples of H, and treating all the values in Clarke's table in the same way as in the phyllotactic examinations of Notes 171–3, so as to obtain, for each element, the ratio, $\frac{1}{4}$ H : (T–O). Although the aggregate evidence of phyllotactic influence upon valency, (3.313 : 1), is nearly 1.6 times as great as the evidence of

hydrogenic influence upon general atomicity, the mathematical probability of the latter is satisfactorily established. I am not aware that the views of Prout and Dalton have ever before been tested in any way like this.

175. *Combination of Harmonic Influences.*

In my studies of cosmical harmony I have often had occasion to speak of the simultaneous operation of different oscillatory tendencies. Similar tendencies, involving similar modifications of resulting rhythms, must exist in the various forms of molecular activity. Dr. Thomas Hill, whose participation in Peirce's investigations of planetary phyllotaxy have given him an interest in other like researches, having suggested that the surd, $\frac{1}{2}(3-\sqrt{5})$, might be more closely represented in the atomic ratios than its phyllotactic approximations, I have tried it upon each of the foregoing groups. I find some evidence of its influence, but the combinations of phyllotactic ratios which are represented by my two divisors, .768 and 1.996, are much more satisfactory. Therefore it seems probable that, although the differences of internal work may prevent any precise atomic commensurability, there are as close approximations to precision in the elementary atoms as there are in plants and in planets.

176. *Fourier's Doctrine of Elasticity.*

The early views of Rittenhouse and other American investigators,* are corroborated by the following extract from Fourier's "*Theorie analytique de la chaleur,*" which is cited by Melsens in his report on Hirn's experimental investigations of the relation which exists between the resistance of the air and its temperature (*Bull. de l'Acad. Roy. de Belgique,* [3] 2, p. 252, 8 *Octobre* 1881).

Art. 53. "La chaleur est le principe de toute élasticité ; c'est sa force répulsive qui conserve la figure des masses solides et le volume des liquides. Dans les substances solides, les molécules voisines céderaient à leur attraction mutuelle, si son effet n'etait pas détruit par la chaleur qui les sépare. Cette force élastique est d'autant plus grande que la température est plus élevée ; c'est pour cela que les corps se dilatent ou se condensent, lorsqu'on élève ou lorsqu'on abaisse leur température."

177. *Test of Atomic Divisors by Arithmetical Means.*

The superiority of the combined phyllotactic divisors, over the surd divisors, Gerber's empirical divisors and the hydrogen unit, may be further shown by comparing the mean percentages of difference from exact multiples of the several divisors, in each of Gerber's groups :

		$\frac{1}{2}(3-\sqrt{5})$.	$\frac{1}{2}(\sqrt{5}-1)$.	H.	Gerber.	Phyllotactic.
For the monatomic	group	.2549	.2404	.2034	.2140	.1804
" trivalent	"	.2322	.2312	.1303	.0878	.0878
" di- or tetratomic	"	.2385	.2755	.2140	.1072	.1044
" metallic	"	.2598	.2543	.2342	.2635	.2546
" combined aggregate		.2501	.2563	.2086	.1931	.1847

* See Proc. Amer. Phil. Soc., xvi, 298 *seq.*

We find, therefore, that in this comparison the evidence of phyllotactic influence upon valency is more striking than that of the hydrogen unit or of Gerber's empirical divisors. In Gerber's special metallic group, however, the hydrogen unit furnishes the nearest, and Gerber's divisor the most remote approximation.

178. *Probable Errors of Atomic Remainders.*

If the deviations from exact multiples of the several divisors are treated as errors of observation, in order to determine the "probable error," we get the following results :

	Accidental.	H.	Gerber.	Phyllotactic.
For the perissads	± .0502	± .0433	± .0371	± .0300
" artiads	± .0294	± .0280	± .0178	± .0180
For all the elements	± .0266	± .0236	± .0163	± .0154

The legitimacy of this treatment may be questioned, but it cannot be charged with any unjust partiality. The artiads furnish an instance in which Gerber's empirical divisors give the nearest approximation. The hydrogen unit is still the least satisfactory of all.

179. *Deduced Laws of Atomicity.*

Notes 171–8 seem to justify the following conclusions :

1. If all the atomic weights were accurately determined, they would be found to be exact multiples of the hydrogen unit.
2. Chemical combinations are influenced by phyllotactic laws, or by tendencies to division in extreme and mean ratio.
3. Artiad and perissad combining units are different, but connected by phyllotactic ratios.
4. Metallic structure is controlled by phyllotactic laws.

180. *Phyllotactic Relations to Oxygen.*

In Note 138 I showed that 37 of the elements, according to Clarke's table, may be more nearly measured by $\frac{1}{16}$ O, while 26 approximate more closely to exact multiples of H. If we take $\frac{1}{8}$ O = 1.995 H, we get Gerber's di- or tetratomic divisor, from which others may be deduced by simple phyllotactic ratios :

Phyllotactic.		Gerber.	
a	1.995	D_2	1.995
$\beta = \frac{1}{2}\ a$	.9975	H	.9997
$\gamma = \frac{3}{13}\ a$	.7673	D_1	.769
$\delta = \frac{5}{8}\ a$	1.2469	D_4	1.245
$\epsilon = \frac{4}{5}\ \delta$	1.5586	D_3	1.559

The following comparative tables introduce all of Clarke's recalculated atomic weights :

Monatomic ; β, γ, H, D_1.

	Phyllotactic.		Gerber.		Clarke.	Δ_1	Δ_2	Δ_3
H	β	.9975	H	.9997	1.0000	.0000	.0025	.0003
Li	9 γ	6.9357	9 D_1	6.921	7.0073	.0010	.0147	.0125
Na	30 γ	23.0190	30 D_1	23.070	22.998	.0001	.0009	.0031
K	51 γ	39.1323	51 D_1	39.219	39.019	.0005	.0029	.0051
Cs	173 γ	132.7429	172 D_1	132.268	132.583	.0031	.0012	.0024
Fl	25 γ	19.1825	25 D_1	19.225	18.984	.0008	.0103	.0125
Cl	46 γ	35.2958	46 D_1	35.374	35.370	.0106	.0021	.0001
Br	104 γ	79.7992	104 D_1	79.976	79.768	.0029	.0004	.0026
I	165 γ	126.6045	165 D_1	126.885	126.557	.0035	.0004	.0026
Ag	140 γ	107.4220	140 D_1	107.660	107.675	.0030	.0024	.0001
Tl	265 γ	203.3345	265 D_1	203.785	203.715	.0014	.0019	.0003
Rb	111 γ	85.1703	111 D_1	85.359	85.251	.0029	.0009	.0013

I have added Tl and Rb to the elements which Gerber included in his monatomic group. Δ_1, Δ_2 Δ_3, are the ratios of the differences between H, γ and D_1, respectively, and the values which may be found by a division of Clarke's atomicities by the theoretical atomicities. The arithmetical mean values correspond with the order of arrangement, viz. : Δ_1, .0028 ; Δ_2, .0034 ; Δ_3, .0036.

Di- or Tetratomic ; $a = D_2$.

	Phyl., Gerber.		Clarke.	Δ_1	$\Delta_2 = \Delta_3$
O	8 D_2	15.96	15.9633	.0023	.0002
S	16 D_2	31.92	31.984	.0005	.0020
Se	39 D_2	77.805	78.797	.0026	.0126
Te	64 D_2	127.68	127.960	.0003	.0023
Mg	12 D_2	23.94	23.959	.0017	.0008
Ca	20 D_2	39.90	39.990	.0002	.0023
Sr	44 D_2	87.78	87.374	.0043	.0046
Ba	69 D_2	137.655	136.763	.0017	.0065
C	6 D_2	11.97	11.9736	.0022	.0003
Si	14 D_2	27.93	28.195	.0069	.0095
Ti	25 D_2	49.875	49.846	.0031	.0006
Zr	45 D_2	89.775	89.367	.0041	.0046
Sn	59 D_2	117.705	117.698	.0026	.0001
Hg	100 D_2	199.50	199.712	.0014	.0011
Mo	48 D_2	95.76	95.527	.0049	.0024
W	92 D_2	183.54	183.610	.0021	.0004
U	120 D_2	239.40	238.482	.0020	.0038

These are the same elements as are embraced in Gerber's second group. The arithmetical mean values of the deviations are, Δ_1, .0025 ; Δ_2, Δ_3, .0033.

Tri- or Pentavalent ; ε, D_3.

	Phyllotactic.		Gerber.		Clarke.	Δ_1	Δ_2	Δ_3
N	9 ε	14.0274	9 D_3	14.031	14.021	.0015	.0005	.0007
P	20 ε	31.1720	20 D_3	31.180	30.958	.0014	.0069	.0071
As	48 ε	74.8128	48 D_3	74.832	74.918	.0011	.0014	.0012
Sb	77 ε	120.0122	77 D_3	120.043	119.955	.0004	.0005	.0007
Bi	133 ε	207.2938	133 D_3	207.347	207.523	.0023	.0011	.0009
Au	126 ε	196.3836	126 D_3	196.434	196.155	.0008	.0012	.0014
Bo	7 ε	10.9102	7 D_3	10.913	10.941	.0054	.0028	.0026
Ta	117 ε	182.3562	117 D_3	182.403	182.144	.0008	.0012	.0014
V	33 ε	51.4338	33 D_3	51.447	51.256	.0050	.0035	.0037

I have added Bo, Ta and V to the elements which Gerber included in this group. The arithmetical mean values of the deviations are, Δ_1, .00208 ; Δ_2, .00212 ; Δ_3, .00215.

Metallic ; δ, D_4.

	Phyllotactic.		Gerber.		Clarke.	Δ_1	Δ_2	Δ_3
Gl	7 δ	8.7283	7 D_4	8.715	9.085	.0094	.0408	.0411
Al	22 δ	27.4318	22 D_4	27.390	27.009	.0003	.0154	.0141
Sc	35 δ	43.6415	35 D_4	43.575	43.980	.0005	.0078	.0092
Cr	42 δ	52.3698	42 D_4	52.290	52.009	.0002	.0069	.0054
Fe	45 δ	56.1105	45 D_4	56.025	55.913	.0016	.0035	.0020
Ga	55 δ	68.5795	55 D_4	68.475	68.854	.0021	.0040	.0055
In	91 δ	113.4679	91 D_4	113.295	113.398	.0035	.0006	.0009
Zn	52 δ	64.8388	52 D_4	64.740	64.905	.0015	.0010	.0025
Cd	90 δ	112.2210	90 D_4	112.050	111.770	.0021	.0040	.0025
Mn	43 δ	53.6167	43 D_4	53.535	53.906	.0017	.0054	.0069
Ni	46 δ	57.3574	47 D_4	58.515	57.928	.0012	.0099	.0101
Co	47 δ	58.6043	47 D_4	58.515	58.887	.0019	.0048	.0063
Cu	51 δ	63.5919	51 D_4	63.495	63.173	.0027	.0066	.0051
Pb	166 δ	206.9854	166 D_4	206.670	206.471	.0023	.0025	.0010
Ru	84 δ	104.7396	84 D_4	104.580	104.217	.0021	.0050	.0035
Rd	83 δ	103.4927	84 D_4	104.580	104.055	.0005	.0054	.0050
Pd	85 δ	105.9865	85 D_4	105.825	105.737	.0025	.0024	.0008
Ir	155 δ	193.2695	155 D_4	192.975	192.651	.0018	.0032	.0017
Pt	156 δ	194.5164	156 D_4	194.220	194.415	.0021	.0005	.0010
Os	159 δ	198.2571	159 D_4	197.955	198.494	.0025	.0012	.0027
Yt	72 δ	89.7768	72 D_4	89.640	89.816	.0020	.0004	.0020
Ce	113 δ	140.8997	113 D_4	140.685	140.424	.0030	.0034	.0019
La	111 δ	138.4059	111 D_4	138.195	138.526	.0034	.0009	.0024
Di	116 δ	144.6404	116 D_4	144.420	144.573	.0029	.0005	.0011
Er	133 δ	165.8377	133 D_4	165.585	165.891	.0007	.0003	.0018
Th	187 δ	233.1703	187 D_4	232.815	233.414	.0018	.0010	.0026
Ytter	139 δ	173.3191	139 D_4	173.055	172.761	.0014	.0032	.0017

The mean deviations are, Δ_1, .00227 ; Δ_2, .00521 ; Δ_3, .00515. In order

to complete the data for comparisons of probable error, I repeat this group, with artiad divisors.

Metallic, II; $a = D_2$.

Gl	5 D_2	9.975	.0890	Ru	52 D_2	103.740	.0046
Al	14 D_2	27.930	.0329	Rd	52 D_2	103.740	.0030
Sc	22 D_2	43.890	.0020	Pd	53 D_2	105.735	.0000
Cr	26 D_2	51.870	.0027	Ir	97 D_2	193.515	.0045
Fe	28 D_2	55.860	.0009	Pt	97 D_2	193.515	.0046
Ga	35 D_2	69.825	.0139	Os	99 D_2	197.505	.0050
In	57 D_2	113.715	.0028	Yt	45 D_2	89.775	.0005
Zn	33 D_2	65.835	1.041	Ce	70 D_2	139.650	.0055
Cd	56 D_2	111.720	.0004	La	69 D_2	137.655	.0063
Mn	27 D_2	53.865	.0008	Di	72 D_2	143.640	.0065
Ni	29 D_2	57.855	.0013	Er	83 D_2	165.585	.0018
Co	30 D_2	59.850	.0161	Th	117 D_2	233.415	.0000
Cu	32 D_2	63.840	.0104	Ytter	87 D_2	173.565	.0046
Pb	103 D_2	205.485	.0048				

The mean deviation is .00885.

181. *Comparative Summary.*

Although I have shown in Note 149, that Schuster's test will often fail to detect harmonies which really exist, it may be used with advantage in many instances of comparative probability. The following tables seem to furnish indisputable evidence of phyllotactic influence upon atomicity.

Logarithms of Probability.

Groups.	Phyllotactic.	Gerber.	Hydrogen.
Monatomic,	3.7476668	3.6572183	5.1634821
Tri- and Pentavalent,	5.2591327	5.2591327	3.8626605
Di- and Tetratomic,	12.0650575	11.9044217	5.1740365
Metallic,	3.0609802	1.2331805	6.1850405
Aggregate,	24.1328372	22.0539532	20.3852196
Mean,	.3770756	.3445930	.3185191

Arithmetical Residuals.

Groups.	Phyllotactic.	Gerber.	Hydrogen.
Monatomic,	.1672	.1947	.2842
3 and 5,	.0926	.0926	.1423
2 and 4,	.1059	.1442	.2119
Metallic,	.2487	.2523	.2247
Mean,	.1748	.1912	.2199

Relative Probability.

Groups.	Phyllotactic.	Gerber.	Hydrogen.
Monatomic,	1.2315	1.0000	32.0822
3 and 5,	24.9156	24.9156	1.0000
2 and 4,	7780740.	5375080.	1.0000
Metallic,	67.2666	1.0000	89507.6
Aggregate,	5592.649	46.637	1.0000
Mean,	1.144	1.062	1.0000

Relative Residuals,

Groups.	Phyllotactic.	Gerber.	Hydrogen.
Monatomic,	1.0000	1.1645	1.6998
3 and 5,	1.0000	1.0000	1.5367
2 and 4,	1.0000	1.3617	2.0009
Metallic,	1.1068	1.1229	1.0000
Mean,	1.0000	1.0938	1.2580

The "logarithms of probability" are deduced from the first four groupings of Note 180, by the method and with the phyllotactic values which were adopted in Notes 171–4. They assign a greater degree of importance to the strictly phyllotactic than to Gerber's approximately phyllotactic divisors, in every instance; a greater degree of importance to the hydrogen divisor than to either the strictly phyllotactic or the approximately phyllotactic divisors, in the monatomic and metallic groups: a greater degree of importance both to the phyllotactic and to Gerber's divisors than to the hydrogen divisor, in the 3 and 5, 2 and 4, aggregate and mean groups.

The "arithmetical residuals" are deduced from the first four groupings of Note 180, by dividing the differences from exact multiples of the several divisors by the respective divisors, by the method which was adopted in Note 177. In this aspect of the question, as in Note 177, the hydrogen unit is most important in the metallic group; the phyllotactic divisors, in each of the other groups; Gerber's coinciding with the phyllotactic in the tri- and pentavalent groups.

The "relative probability" and "relative residuals" are found by taking the least value in each group as the unit. The indications are, of course, the same as in the systems of grouping from which they were derived. In the metallic group the probability of predominant hydrogen influence is 89507.6 times as great as that of Gerber's divisors, or 1330.6 times as great as that of the phyllotactic divisors. In the di- and tetratomic group the phyllotactic probability is more than 7780740 times as great as that of the hydrogen divisor, or 1.4475 times as great as that of Gerber's divisors. The aggregate phyllotactic probability is 15592.649 times as great as that of the hydrogen divisor, or 119.918 times as great as that of Gerber's divisors.

182. *Synopsis of Probable Errors.*

The following tables are computed on the hypothesis that the atomic weights are exact multiples of the several divisors. The percentages of the divisors which represent $(T - O) \div D$,* are treated as errors of observation, and the probable errors are deduced in the usual way. Those percentages may evidently vary between 0 and $\pm .5$.

* See Note 171.

Probable Errors.

Groups.	Surd I.	Surd II.	Hydrogen.	Gerber.	Phyllotactic.
Monatomic,	± .0529	± .0545	± .0552	± .0490	± .0407
3 and 5,	± .0588	± .0556	± .0445	± .0253	± .0253
2 and 4,	± .0438	± .0497	± .0439	± .0357	± .0218
Metallic,	± .0375	± .0385	± .0358	± .0358	± .0361
Aggregate,	± .0232	± .0242	± .0222	± .0200	± .0181

Relative Probable Errors.

Groups.	Surd. I.	Surd. II.	Hydrogen.	Gerber.	Phyllotactic.
Monatomic,	1.3001	1.3401	1.3571	1.2038	1.0000
3 and 5,	2.3211	2.1933	1.7559	1.0000	1.0000
2 and 4,	2.0101	2.2764	2.0109	1.6361	1.0000
Metallic,	1.0473	1.0752	1.0004	1.0000	1.0085
Aggregate,	1.2812	1.3394	1.2274	1.1079	1.0000

Surd I is $\frac{1}{2}(3 - \sqrt{5})$; Surd II, $\frac{1}{2}(\sqrt{5} - 1)$. The groupings and the phyllotactic divisors are the same as in the foregoing note. Phyllotactic precedence is shown in eight of the groups; Gerber's approximately phyllotactic in four; hydrogen in one. Surd divisors take precedence of hydrogen in four of the groups. They suggest the probability that dextro- and lævo-gyration may be phyllotactic phenomena, originating in tendencies to division in extreme and mean ratio.

183. *Probabilities of the Surd Divisors.*

In order to show the character of the evidence to which I referred in Note 175, and thus complete the comparative examination which I have undertaken, I add the following tables.

	Logarithms of Probability.		*Arithmetical Residuals.*	
Groups.	Surd I.	Surd II.	Surd I.	Surd II.
Monatomic,	.6805064	.9997215	.240	.239
3 and 5,	1.4766962	1.1496250	.231	.226
2 and 4,	3.4829337	.1602944	.238	.275
Metallic,	1.7491278	1.4979853	.260	.266
Aggregate,	7.3893241	3.8076262	.247	.258
Mean,	.1154582	.0594942	....	....

The arithmetical residuals are so near Schuster's limit that they furnish but slight evidence of harmonic influence. The mean probabilities, 1.304 and 1.147, are also comparatively small, but inasmuch as each of the groups indicates a decided probability, while the aggregates are more than 24,500,000 and 6420 respectively, any hypothesis of accidental determination must be rejected. Perhaps the most important use which we can make of the results is to extend the comparisons of the foregoing note, so as to add further cogency to the proof of phyllotactic sway.

Relative Probability.

	Phyllotactic.	Gerber.	Hydrogen.	Surd I.	Surd II.
Aggregate	$21145(10)^{16}$	$1763(10)^{15}$	$378(10)^{14}$	3816.8	1
Mean	2.078	1.928	1.815	1.138	1
Residual	1.476	1.349	1.173	1.044	1

184. *Another Comparative Summary.*

If we take the percentages of deviation, instead of the fractional deviations from exact multiples of the several divisors, and divide by the number of hydrogen units which most nearly represents each of Clarke's atomic weights, we obtain data for computing other probabilities and probable errors, which are given below:

Logarithms of Relative Probability.

Groups.	Phyllotactic.	Gerber.	Hydrogen.	Surd I.	Surd. II.
Monatomic	5.0490205	4.6466652	5.7455887	.0000000	2.7689906
3 and 5	4.5555159	4.5555159	2.8622287	.0000000	.0090219
2 and 4	12.2941388	10.7902815	4.5435830	1.0009281	.0000000
Metallic	.5855468	.0000000	4.1708538	.2005275	.2278172
Aggregate	21.2824664	18.7910070	16.1207986	.0000000	1.8043741
Mean	.3325385	.2936095	.2518875	.0000000	.0281933

Probable Errors.

Groups.	Phyllotactic.	Gerber.	Hydrogen.	Surd I.	Surd II.
Monatomic	± .00117	± .00153	± .00100	± .00393	± .00328
3 and 5	± .00042	± .00042	± .00059	± .00290	± .00264
2 and 4	± .00035	± .00039	± .00050	± .00221	± .00161
Metallic	± .00065	± .00098	± .00117	± .00076	± .00096
Aggregate	± .00036	± .00051	± .00028	± .00103	± .00090

185. *Incipient Phyllotaxy.*

The probable errors both in Note 182 and in Note 184, seem to give more indications than are furnished by the relative probabilities, of surd influence upon atomicity. There is room, however, for a reasonable doubt whether those indications are other than accidental, and it would undoubtedly be desirable, if it were possible, to find some more satisfactory test of probabilities which are so near to the boundary line between normal and casual coincidences. In the aggregate probabilities, hydrogen stands between the surd divisors and the phyllotactic divisors. The latter were tested by elements which are denser than hydrogen, and, therefore, have a greater atomic inertia. Is it not likely that the former may find their rightful province in a more æthereal region, either in the primitive "subsidence" of nebulous matter or in the undulations which precede subsidence? Cyclical tendencies may naturally become more marked as solidification increases.

186. *Foreshadowings.*

The greatest superiority of S_1 over S_2, as well as of the phyllotactic and approximately phyllotactic divisors over the hydrogen divisor, is found in the di- and tetratomic group. The aggregate probability of hydrogen influence on atomicity is more than 9,900,000,000,000 times as great as that of S_1, or more than 37,800,000,000,000,000 times as great as that of S_2, or more than 242,700,000,000,000,000,000 times the probability of accidental coincidence. Each of these numbers should be multiplied by 5592.6 to give the probability of the phyllotactic divisors. The lowest surd probability in either group is that of S_2 in the di- and tetratomic group, which is only 1.446 : 1, or a little more than 13 : 9. Even this ratio, however, is satisfactory as indicative of incipient action, and suggestive of researches in the "nascent state," the "fourth state of matter," or in some other approximation to the æthereal condition. The artiad and metallic elements seem also to offer fields for important future discovery in regard to modifications of phyllotactic tendency by condensation or combination.

187. *Hydrogen Shares the Phyllotactic Probabilities.*

In the foregoing notes I have treated hydrogen as outside the phyllotactic group, in order to find the probability of the hypotheses of Dalton and Prout as compared with other reasonable hypotheses. As a member of the phyllotactic group, and the most general of the phyllotactic divisors, it shares all the probabilities of the group. Therefore, if there is any value in mathematical tests, the views of Berzelius, Turner, Marignac, Stas and Clarke, as to the importance of the hydrogen atom, should be accepted, rather than those of Thomas Thomson and Dumas.

188. *Inertia and Elasticity.*

Thus the evidences are multiplying, in every direction, of the importance of giving great heed to the blended sway of inertia and elasticity, in all physical researches. The moment of inertia is of especial importance, inasmuch as material particles, in an elastic medium, become the seats of living forces which enable us to apply the laws of composition and resolution of forces, to composition and resolution of motions. The principles which I applied successfully, in 1863, to barometric estimates of the Sun's mass and distance, have been abundantly exemplified in every field in which I have sought for evidences of their influence, and now they are found at the very threshold of material structure, where cohesive and chemical attractions first show themselves.

189. *Phyllotaxy of Central Force.*

I have already spoken of the appearance of the phyllotactic numbers 1, 2, 3, 5 and 8, in crystallization, and especially in the mimicry of frost-pictures. The simplest phenomena of central force introduce the first three phyllotactic powers; Kepler's third law gives the phyllotactic frac-

tional exponent $\frac{3}{2}$; the actions and reactions of elasticity and inertia in nucleation, assign, as I have shown, the product of two phyllotactic exponents, $2 \times \frac{3}{2} = \frac{3}{4}$. in the ratio of variability between the nucleal radius and Laplace's limiting radius; the relations between density and distance, in elastic media, change exponential to numerical coefficients. All of these phyllotactic relations spring from simple and elementary mathematical principles, to which the actions of central force must yield. If we call the fundamental force radiodynamic, we may be continually reminded of its alternating centripetal and centrifugal tendencies. If we call it photodynamic, the term will be naturally suggestive of the all-pervading elasticity or quasi-elasticity which propagates the rays of light and thus becomes the medium through which we get all our knowledge of heavenly bodies, as well as the largest portion of our knowledge of all earthly phenomena.

190. *Phyllotaxy of Virtual Areas.*

The planetary virtual areas, Notes 159 and 164, are jointly related through the last two of the elementary phyllotactic principles of the foregoing note. Beginning with the largest and primitively central planetary mass, the laws of nucleation and elasticity, acting first outwardly from the Sun and then inwardly, help to determine the reactionary *vis viva* of Saturn, Neptune, Uranus, Earth, Venus, Mars and Mercury, in regular succession. In passing from the extra-asteroidal to the intra-asteroidal group, another phyllotactic succession of phyllotactic ratios shows itself, the ratio between the harmonic areas* of Uranus and Earth being, within less than $1\frac{1}{4}$ per cent., $(\frac{2}{3})^6$, the exponent being the phyllotactic product 2×3. This is also the coefficient of orbital retardation at the centre of the belt of greatest condensation; it is the $\frac{3}{4}$ power of the ratio between the harmonic areas of Jupiter and Earth, thus pointing to Uranus as a nucleal locus for which Jupiter represents Laplace's limit; the locus of secular perihelion, or incipient rupture, for Uranus, is nucleally central between the mean loci of Jupiter and Neptune; Uranus and Earth are at opposite extremities of a major-axis which would be traversed by light in the same time that Sun would rotate, if it were condensed until its present equatorial radius became Laplace's limiting radius. These five accordances present a chain of phyllotactic and photodynamic influences which seems worthy of further study.

191. *Optical and Thermal Relations in Organic Liquids.*

Brühl (*Ber. Berl. Chem. Ges.* xiv, 2533, Nov. 1881; cited in *Am. Jour. Sci.* [3], xxiii, 234), finds that progressive oxidation has the same influence on the optical as on the thermal properties of organic liquids, the refractive power diminishing as the amount of oxygen is increased, precisely as the heat of combination diminishes. Removal of hydrogen or its replacement by oxygen produces the same effect, so that both the above physical values

* The ratio of the actual virtual areas is within $\frac{1}{25}$ of one per cent. of $(\frac{2}{3})^6$.

are greater for the hydrocarbons than for the alcohols, aldehydes, acids, etc., derived from them.

192. *Subsidiary Phyllotaxy.*

Gerber (*Les Mondes*, [3] i, 145), after referring to the accuracy with which the atomic weights of nearly one-half of the chemical elements have been determined, says :—"Un pareil degré de rigueur ne saurait être atteint dans l'application des lois d'Avogadro, de Dulong et Petit, de Mitscherlich. Celles-ci, comme il a été dit, sont des *lois de conditions*, dont nous ne possédons qu' une formule provisoire." The phyllotactic approximations are so much closer than those which are here spoken of, that we may well hope for some important results from their subsidiary employment in stoichiometry.

193. *Glucinum.*

Gerber (*l. c.* pp. 146-9), thinks that the law of Dulong and Petit accords better with the atomic weight which Nilson and Petersson assign to Glucinum, 13.65, than with the one which is adopted by Mayer and Mendelejeff, 9.1. The same thing may be said of the phyllotactic and the approximately phyllotactic divisors, for $13.65 = 11 \times 1.245 - .045 = 11 \times 1.247 - .067$, while $9.1 = 7 \times 1.245 + .385 = 7 \times 1.247 + .371$, the residuals being, respectively, 8.5 and 5.5 times as great in the latter case as in the former. This single change would increase the superiority in relative probability, of the phyllotactic divisors over the hydrogen divisor, more than twelve fold.

194. *"The Principles of Magnetism."*

Charles Morris (*Jour. of Sci.*, [3] iv, 71) objects to the magnetic theories of Ampère and Weber, as follows : "The Ampèrian theory is constantly and gravely repeated in text-books, to the present day, without a hint being given of the indisputable fact that it is quite at variance with the principles of energy, as now understood. It is easy to imagine a constant current of electricity, and make it answer a definite purpose, but the truth is that no such thing exists as a constant current of electricity, in the Ampèrian sense." He goes on to speak of the currents of static electricity as being instantaneous, while those of galvanic and thermo-electricity consist of instantaneous components and cease when the chemical or thermal equilibrium is restored. But is the equilibrium in the terrestrial thermal and gravitating currents ever restored? In 1864 (*Proc. A. P. S.*, ix, 357, foot-note) I showed that the opposing forces of rotation, elasticity and gravitation must produce oscillations. In various preceding and subsequent papers I showed that those oscillations must produce constant currents of such descriptions as Ampère supposed.

195. *Dogmatism.*

Many modern investigators, who pride themselves on their freedom from the dreams of metaphysics, continually fall into ways which they

theoretically condemn. There is fully as much dogmatism in physics as in metaphysics. Whenever it springs from a well-grounded conviction, which has been once thoroughly tested and which always courts a repetition of tests, it is not only unobjectionable but it is highly commendable. On the other hand when it is merely theoretical, or the outgrowth of inveterate prejudice, it has no rightful place in any discussion which claims to be scientific.

196. *Numerical Tests.*

There has been an immense amount of valuable mathematical analysis which has been misunderstood, or but partially understood, for want of being properly tested. Results are never valid except for the data which they embody; they are always subject to modification by neglected, unknown or new data. The "opprobrium of thermodynamics" amounts to nothing more than the statement that, from the data which have been discussed hitherto, there appears to be a universal tendency to physical stagnation and death. The principle of equal action and reaction ought to furnish some means of escape from this opprobrium. The way of escape seems to have been indicated by the identification of a common operative velocity in light, electricity, chemistry and gravitation. A single theoretical result which has been quantitatively verified, is worth more than a thousand that are thought to be beyond the reach of verification. The theory of dependent connection between stellar rotary oscillations and the reaction of cosmical inertia against æthereal influence (Note 162 *et al.*), having been verified by the test of our Sun, seems likely to open the way for a general recognition of an æthereal reaction which will yield an exact compensation for all physical actions, affording a more satisfactory explanation of stellar light and heat than can be drawn from meteoric or shrinkage hypotheses.

197. *Velocity of Gravitating Action.*

Objections have been urged against the possibility of making gravitation the effect of light undulations unless we first overthrow Laplace's conclusion, that gravity must act with at least a hundred million times the velocity of light and that its action may be regarded as instantaneous. I answer :— 1. I have never claimed that any physical phenomenon is the effect of another physical phenomenon, but merely that the phenomena of light and gravitation are so related as to show that they may be effects of a common cause. 2. The rapidity of action and the rapidity with which the results of the action are propagated are two entirely different things. 3. If the results of gravitating and luminous actions and reactions are identified in stellar rotations, it is altogether likely that the forces upon which these results depend act with equal speed. 4. Even if it should be found necessary to propagate gravitating undulations with a hundred million times the velocity of light, it would be as easy to suppose a gravitating æther, with a ratio of elasticity to density which is $(100,000,000)^2$ times that of the

luminiferous æther, as it is to suppose a luminiferous æther. 5. All nebular, æthereal, and other unverifiable hypotheses are useful only so far as they serve to cōordinate categories of phenomena which occur as they would if the hypotheses were true. 6. I showed, long ago, that no merely physical theory or hypothesis has ever been framed which would explain the instantaneous transmission of velocity, and that such transmission, if it exists and is not physical, must be regarded as spiritual.

198. *Varying Gravitating Velocities.*

The foregoing objections may be further obviated by a consideration of the fact that gravitating velocities begin with mere tendencies to motion, and that some time must elapse before the velocity becomes appreciable. The difficulty which Faraday found, in reconciling the conservation of energy and the correlations of force with gravitating tendencies which vary inversely as the square of the distance, is a mathematical difficulty which is equally involved in heat, light, electricity and all other manifestations of radiant energy. The element of constancy may be found in a uniform elementary velocity, as in the general expression for stellar gravitating acceleration, $g_n = \frac{v_\lambda}{t_n}$ in which g_n is the acceleration of a particle at the distance n, v_λ, is the velocity of light, and t_n is the time of a single oscillation or half-rotation if the star were uniformly expanded until it had a radius equal to n.

199. *Commensurability and Incommensurability.*

In his original paper (*Math. Monthly*, i, 245), Chauncey Wright said: "But if now we seek a uniform and symmetrical distribution as well as a thorough one, the interval between the successive points must be constant, and if the circumference is to be indefinitely subdivided, this interval is, of course, incommensurate." Such indefinite subdivision can hardly be looked for in any of the ordinary concrete physical phenomena, hence we find that the chemical and other approximations which we have examined are better represented by exact phyllotactic ratios than by the surd distributive tendencies. Still it seems likely that the want of precise commensurability, which is found in Clarke's table, may arise from a residual tendency to indefinite subdivision, and for this reason we may find that no increased accuracy in the determination of atomic weights will lead to the establishment of any series of divisors which are absolutely exact. I can think of no case in which the incommensurability of the surd divisors seems likely to be more completely represented than in the Ampèrian currents (Note 194).

200. *"Celestial Chemistry."*

Dr. T. Sterry Hunt (*Proc. Camb. Phil. Soc.*, reprinted in *Am. Jour. Sci.*, Feb. 1882), recites "certain views enunciated almost simultaneously by the late Sir Benjamin Brodie, of Oxford, and" himself, in the line of

development and extension of "the remarkable perception of great chemical truths which is apparent in the queries appended to the third book of Newton's *Optics*, as well as in his hypothesis touching Light and Color." Brodie's first announcement of the assumed existence of certain ideal elements was read before the Royal Society, May 3, 1866, and in the Spring of 1867 Hunt "spent several days in Paris with the late Henri Sainte-Claire Deville, repeating with him some of his remarkable experiments in chemical dissociation, the theory of which [they] then discussed in its relations to Faye's solar hypothesis." I first invited attention to the "nascent" cosmical equation, or the equation which marks the limiting velocity between tendencies to cosmical aggregation and to cosmical dissociation $v = \frac{gt}{2}$, on Dec. 18, 1863 (*Proc. Am. Phil. Soc.*, ix, 284 7). On April 1, 1864 (*Ib.*, p. 357), I said: "Absolute rest is apparently an impossible condition of matter, for, to whatever extent the action of opposing forces may be relatively neutralized, the inconceivable rapidity of æthereal, planetary and stellar motions produces a constant change of place. * * * The sum of all the instantaneous energies is the same, whether the particle fall freely for any given time, or remain apparently at rest. All the potential energy which is transformed in one case into the actual energy of motion, in the other is counteracted by an equivalent and opposite actual energy of elasticity." On July 15, 1864 (*Ib.* p. 408), I suggested "that one of the most probable results of the rotation of the Earth with its atmosphere, in an æthereal medium, would be the production of two systems of oscillations, moving with the rapidity of light." In October and December, 1864, I presented to the American Philosophical Society the "Numerical relations of gravity and magnetism," for which the Society awarded its Magellanic gold medal, as furnishing "good reason to hope that by the application of mechanical laws to the several phases of the æthereal undulations which produce the phenomena of light, heat, electricity, polarity, aggregation and diffusion, we may obtain a clearer understanding, not only of all the meteorological changes, but also of seismic tremors, crystallization, stratification, chemical action, and general morphology," (*Ib.*, p. 439). On Sept. 21, 1866 (*Op. cit.*, x. 269), I gave my first indication of the photodynamic importance of Earth's situation at the centre of the belt of greatest condensation, and on April 2, 1869 (*Ib.*, xi, 106–7), I showed that Sun's nascent or dissociative velocity is the velocity of light.

201. *Nitrogen and the Perissads.*

If Newton's belief that the inter-stellar æther is an expanded, universal atmosphere, is true, it seems likely that the two principal constituent gases of our own atmosphere may be everywhere as abundant, relatively, as they are within the reach of our immediate observation. Even if this is not the case, we may reasonably look for some special mathematical evidences of the importance of two gases which have so wide a local diffusion, and which have so large a sway in chemical combination and in organic

growth. In Note 54 I showed that a large number of the elements contain either 7 or 8, as one of the factors of the integers which most nearly represent their atomicity according to the hypotheses of Dalton and Prout. These two numbers denote respectively the simplest phyllotactic sub-multiples of N and O. If we use the former as a divisor of the perissads, treating the remainders as in the foregoing notes, we get the following results:

$D_p = 7.$

	Coefficient of D.	Remainder.	Log. R.
Li	1	+ .0073	$\bar{3}$.8633229
Na	3	+ 1.998	.3005955
K	6	— 2.981	.4743620
Cs	19	— .417	$\bar{1}$.6201360
Fl	3	— 2.016	.3044905
Cl	5	+ .370	$\bar{1}$.5682017
Br	11	+ 2.768	.4421661
I	18	+ .557	$\bar{1}$.7458552
Ag	15	+ 2.675	.4273238
Tl	29	+ .715	$\bar{1}$.8543060
Rb	12	+ 1.251	.0972573
	Sum of Monatomic logarithms		$\bar{2}$.6980170
N	2	+ .021	$\bar{2}$.3222193
P	4	+ 2.958	.4709982
As	11	— 2.082	.3184807
Sb	17	+ .955	$\bar{1}$.9800034
Bi	30	— 2.477	.3939260
Au	28	+ .155	$\bar{1}$.1903317
Bo	2	— 3.059	.4855795
Ta	26	+ .144	$\bar{1}$.1583625
V	7	+ 2.256	.3533391
	Sum of Tri- or Pentavalent logarithms		$\bar{2}$.6732404

Log. of Monatomic probability; $\log. 1.75^{11} - \bar{2}.6980170 = 3.9754016$
" Tri- and Pentavalent " ; " $1.75^{9} - \bar{2}.6732404 = 3.5141020$
" Total Perissad 7.4895036

202. *Oxygen and the Artiads.*

If we use 8 as a divisor of the Artiads, we get the following results:

$D_a = 8.$

	Coefficient of D.	Remainder.	Log. R.
O	2	— .0367	$\bar{2}$.5646661
S	4	— .016	$\bar{2}$.2041200
Se	10	— 1.203	.0802656
Te	16	— .040	$\bar{2}$.6020600
Mg	3	— .041	$\bar{2}$.6127839

	Coefficient of D.	Remainder.	Log. R.
Ca	5	— .010	$\bar{2}$.0000000
Sr	11	— .626	$\bar{1}$.7965743
Ba	17	+ .763	$\bar{1}$.8825245
C	1	+ 3.9736	.5991841
Si	4	— 3.805	.5803547
Ti	6	+ 1.846	.2662317
Zr	11	— 1.367	.1357685
Sn	15	— 2.302	.3621053
Hg	25	— .288	$\bar{1}$.4593925
Mo	12	— .473	$\bar{1}$.6748611
W	23	— .390	$\bar{1}$.5910646
U	30	— 1.518	.1812718
	Sum of Di- and Tetratomic logarithms		$\bar{3}$.5932287
Gl	1	+ 1.085	.0354297
Al	3	+ 3.009	.4784222
Sc	5	+ 3.980	.5998831
Cr	7	— 3.991	.6010817
Fe	7	— .087	$\bar{2}$.9395192
Ga	9	— 3.146	.4977587
In	14	+ 1.398	.1455072
Zn	8	+ .905	$\bar{1}$.9566486
Cd	14	— .230	$\bar{1}$.3617278
Mn	7	— 2.094	.3209767
Ni	7	+ 1.928	.2851070
Co	7	+ 2.887	.4604468
Cu	8	— .827	$\bar{1}$.9175055
Pb	26	— 1.529	.1844075
Ru	13	+ .217	$\bar{1}$.3364597
Rd	13	+ .055	$\bar{2}$.7403627
Pd	13	+ 1.737	.2397998
Ir	24	+ .651	$\bar{1}$.8135810
Pt	24	+ 2.415	.3829171
Os	25	— 1.506	.1778250
Yt	11	+ 1.816	.2591158
Ce	18	+ 3.576	.5533975
La	17	+ 2.526	.4024333
Di	18	+ .573	$\bar{1}$.7581546
Er	21	— 2.109	.3240766
Th	29	+ 1.414	.1504494
Yb	22	— 3.239	.5104109
	Sum of Metallic logarithms,		2.4334051

Log. of Di- and Tetratomic probability; log. 2^{17}	—	8.5932287	= 12.5242813
" Metallic " "	"	2^{27} — 2.4334051	= 5.6944049
" Total Artiad "			18.2186862
" Aggregate, Per. and Art. "			25.7081898
" Mean "			.4016920

By reference to Notes 181 and 183, it will be seen that the aggregate probability of atmospheric phyllotactic influence is more than 37.6 times as great as that of simple phyllotactic influence, more than 4510 times as great as that of Gerber's divisors, more than 210363 times as great as that of the hydrogen divisor, or more than 2,083,840,000,000,000,000 times as great as that of the first surd divisor.

203. *Precipitability.*

The Philosophical Magazine for March 1882, contains two papers, one by Mills and Bicket, the other by Mills and Hunt, on chemical equivalence, as estimated by "equivalent precipitability of sulphates, by sodic carbonate, from an aqueous solution." Among the conclusions which they have drawn from their work the following seem to be especially noteworthy :—1. Precipitability is a linear function of mass. 2. There is some evidence that the precipitabilities of the commixed and separate sulphates are mathematically related in a simple manner. 3. Within moderate limits, precipitation is not traceably affected by temperature. 4. Two elements belong to the same group when, in saline solutions of identical genus, they may be equally precipitable. The simplicity and character of these conclusions are such as to suggest æthereal influence, a suggestion which is strengthened by the final equation, $\nu = \delta = .3819$; ν and δ being, respectively, the ratio of precipitability to the quantity of nickelous and cadmic sulphate taken. The ratio is the same, to the fourth decimal place, as the first surd divisor in extreme and mean ratio, .381966, thus indicating a beginning of phyllotactic tendency which is very satisfactory.

204. *Electrical Conductivity of Gases.*

Edlund (*P. Mag.* [5] xiii, 201), cites the experiments of Edm. Becquerel (*Ann. de Ch. et de Ph.* [3] xxxix, 377), showing "that gases begin to be conductors when heated to the temperature of redness, after which their conductivity increases in proportion as the temperature rises above that point," the conductivity increasing as the density of the gas diminishes. This approach to the æthereal condition is also an approach to the fundamental æthereal *vis viva*, which is shown by the identity of velocity in the propagation of luminous undulations, the electrical "ratio," and the gravitating reactions of stellar rotation.

205. *Ratio of Æthereal Elasticity to Density.*

In my first approximation to the ratio between atmospheric and æthereal elasticities (*Proc. Amer. Phil. Soc.*, ix, 440), I followed Herschel, in supposing that the velocity of light, in the interstellar spaces, is uniform, and that, consequently, the elasticity of free æther varies directly as its density. The same conclusion would follow from Newton's views (See Note 200), and is involved in Edlund's discussions of the relations of electricity to heat. Every additional evidence of harmonic relations, that is brought to light through the application of the laws of gaseous elasticity to the kinetic æther, is also an additional evidence of the truth of the hypothesis that all physical energy is transmitted by means of a universally diffused elastic medium.

206. *Spectrum of Lightning.*

Schuster (*P. Mag.*, [5] vii, 319), gives some of his measurements, at different times, of lines or bands in the lightning-spectrum, comparing the means with two measurements which Vogel had deduced from his own observations. The harmonic character of the lines is clearly shown by the following tables. The value of a, in the harmonic divisors, is .01578.

Schuster.	Mean.	Vogel.	Harmonic.	Harmonic Divisors
5592			5592	1
5348				
5329	5334	5341	5339	$1 + 3\,a$
5325				
5260			5260	$1 + 4\,a$
5175				
5193	5182	5184	5183	$1 + 5\,a$
5177				

207. *Torsion, Flexion and Magnetism.*

G. Wiedemann (*La Lumière Electrique*, vi, 90), in speaking of results obtained by the torsion of wires and the flexure of rods, says that the phenomena correspond so closely with those of magnetism that the words "torsion" and "magnetism" are almost always interchangeable. This is a further illustration of the identity of fundamental *vis viva*, which was spoken of in Note 204, and which is especially exemplified by the application of Coulomb's torsional coefficient to solar rotation (Note 162). My earliest "numerical relations of gravity and magnetism" (*Proc. Amer. Phil. Soc.*, ix, 355—60, 425—40, *et al.*) were based upon the mechanical consequences of rotation in an elastic medium.

208. *Phyllotaxy and Atomic Heat.*

The constant product of atomic weight by specific heat, 6, which is indicated by the law of Dulong and Petit, is equivalent to the continued product of the first three numbers of the phyllotactic series $1 \times 2 \times 3$. Were

this an isolated fact, little importance could be attached to it, but when we bring it to the test of mathematical probability, it becomes suggestive of relations which may, perhaps, lead to important discoveries. In the following comparison D indicates the estimate of atomic heat which deviates least from 6 (*Meyer, Modernen Theor. d. Chem.* Ed. of 1880, 90, 106); δ_1, the ratio of deviation from exact correspondence with the theoretical value; C, the observed multiples and values of the perissad and artiad divisors (Notes 201—2); δ_2, their deviation from the theoretical values:

	D	δ_1	C	δ_2
Li	6.6	.1000	1 × 7.0	.0000
Na	6.7	.1167	3 × 7.7	.1000
K	6.5	.0833	6 × 6.5	.0714
Fl	5.	.1667	3 × 6.3	.1000
Cl	6.4	.0667	5 × 7.1	.0143
Br	6.7	.1167	11 × 7.3	.0429
I	6.8	.1333	18 × 7.0	.0000
Ag	6.	.0000	15 × 7.2	.0286
Tl	6.8	.1333	29 × 7.0	.0000
Rb	6.4	.0667	12 × 7.1	.0143
N	5.	.1667	2 × 7.0	.0000
P	5.9	.0167	4 × 7.7	.0429
As	6.1	.0167	10 × 7.5	.0714
Sb	6.	.0000	17 × 7.1	.0143
Bi	6.5	.0833	30 × 6.9	.0143
Au	6.4	.0667	28 × 7.0	.0000
Bo	5.5	.0833	2 × 5.5	.0714
O	4.	.3333	2 × 8.0	.0000
S	5.7	.0500	4 × 8.0	.0000
Se	6.	.0000	10 × 7.9	.0125
Te	6.	.0000	16 × 8.0	.0000
Mg	6.	.0000	3 × 8.0	.0000
Ca	6.8	.1333	5 × 8.0	.0000
Sr	6.4	.0667	11 × 7.9	.0125
Ba	6.4	.0667	17 × 8.0	.0000
C	5.5	.0833	1 × 12.0	.5000
Si	5.7	.0500	4 × 7.0	.1250
Ti	6.4	.0667	6 × 8.3	.0375
Zr	6.	.0000	11 × 8.1	.0125
Sn	6.5	.0833	15 × 7.8	.0250
Hg	6.3	.0500	25 × 8.0	.0000
Mo	6.9	.0167	12 × 8.0	.0000
W	6.1	.0167	30 × 7.9	.0125
Gl	5.6	.1000	1 × 9.1	.1375
Al	5.8	.0333	3 × 9.0	.1250
Cr	6.4	.0667	7 × 7.4	.0750

	D	δ_1	C	δ_2
Fe	6.3	.0500	7 × 8.0	.0000
Ga	5.5	.0833	9 × 7.7	.0375
In	6.5	.0833	14 × 8.1	.0125
Zn	6.1	.0167	18 × 8.1	.0125
Cd	6.	.0000	14 × 8.0	.0000
Mn	6.7	.1167	7 × 7.7	.0375
Ni	6.4	.0667	7 × 8.3	.0375
Co	6.3	.0500	7 × 8.4	.0500
Cu	6.	.0000	8 × 7.9	.0125
Pb	6.3	.0500	26 × 7.9	.0125
Ru	6.3	.0500	13 × 8.0	.0000
Rd	6.	.0000	13 × 8.0	.0000
Pd	6.3	.0500	13 × 8.1	.0125
Ir	6.3	.0500	24 × 8.0	.0000
Pt	6.3	.0500	24 × 8.1	.0125
Os	6.2	.0333	25 × 7.9	.0125
Ce	6.3	.0500	18 × 7.8	.0250
La	6.2	.0333	17 × 8.1	.0125
Di	6.4	.0667	18 × 8.0	.0000

This comparison shows that the general deviations from Dulong and Petit's law, while they are of the same order of magnitude, are much greater than the deviations from the perissad and artiad divisors.

209. *Secondary Character of Perissad Phyllotaxy.*

Although the fractions which are formed by successive approximations to the surd divisors represent phyllotactic dextro- and lævo-gyration, other series of a higher order may spring from greater initial differences. If we skip the first even number, we get the series 1, 3, 4, 7, 11, 18, etc. Hence we see that the fundamental perissad and artiad divisors both start from the phyllotactic number which most nearly represents the first surd divisor, 3, and are formed by adding the next artiad number for the perissad divisor, and the next perissad number for the artiad divisor. The coefficient of atomic heat is also formed from the same representative of division in extreme and mean ratio by taking its simplest artiad multiple, 2 × 3.

210. *Comparison of Probabilities.*

In looking more closely into the deviations which are given in Note 208, we find the following indications of superiority in the perissad and artiad divisors:

1. The approximation of the observed values within .05 of the theoretical values occurs 19 times in my columns, and only 9 times in those of Dulong and Petit.
2. The average deviations are, $\delta_1 = .0642$; $\delta_2 = .0344$.

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3. The sums of the logarithms of the reciprocals of deviation, which indicate the aggregate relative probabilities of normal influence, are : 70.4555173 ; 89.2627807.

4. The ratio of aggregate probabilities is, therefore, $P_1 : P_2 :: 1 : 64159\ (10)^{14}$. The ratio of mean probabilities, $P^{\frac{1}{365}}$, is $p_1 : p_2 :: 1 : 2.1976$.

5. Testing the hydrogen unit in a like way, I find the average deviation, $\delta_3 = .0024$; $\Sigma \log (1 \div \delta_3) = 152.5459742$; log. relative probability, taking P_p as the unit, 82.0904569. This gives, $P_3 = 12315\ (10)^{78}$; $p_3 = 31.0852$.

6. In accordance with the principle of least squares, these values of p should be reduced inversely as the fundamental divisors. This gives $p_1 : p_2 : p_3 : p_4 :: 1 : 1.71 : 4.44 : 5.08$; $\log (P_2 \div P_1) = 12.8482860$; $\log (P_3 \div P_1) = 35.6100415$; $\log (P_4 \div P_1) = 38.8306765$; p_4 and P_4 being respectively, the mean and aggregate probabilities of the phyllotactic divisors (Note 181). The corresponding mean relative probabilities for S_1, S_2, and Gerber's divisors are respectively, 2.78, 2.45, 4.72.

211. *Suggestions for Further Investigation.*

The ratio between p_1 and p_2, in the foregoing note, has been gradually diminished by successive approximations, and by making allowance for theoretical considerations, which have seemed to justify the adoption of some exact multiple or submultiple of an atomic weight which had been previously accepted. The ratio between p_1 and p_2, favorable as it already is for the latter, is based upon a comparison of the latest revision of the atomic heats with the first crude application of the perissad and artiad divisors. If Dulong and Petit's law is entitled to great weight in determinations of atomicity, a still stronger claim may be urged in behalf of divisors which have a mean probability that is more than 70 per cent. greater. If Dumas's proposed modification of Prout's hypothesis were applied to Si and Cr, their atomicities would be very closely represented by $\frac{7}{2} \times 8$ and $\frac{13}{2} \times 8$; P is very nearly $\frac{5}{9} \times 8 \times 7$, or very nearly $\frac{40}{9}$ of the monatomic phyllotactic divisor ; Na is about 30 times the monatomic divisor or 2×11, 11 being the phyllotactic number which follows 7 in the secondary series (Note 209) ; Bo is 7.018 times its proper phyllotactic divisor. Si, Cr, Na and P may, perhaps, have tendencies towards the opposite group, perissad or artiad, the investigation of which may throw light upon the beginnings of valency.

212. *Chemical Electricity.*

Davy's discovery of potassium laid the foundation of electrolysis, introducing polarity as an important modifier of chemical attraction. The attractions and repulsions of Sir William Thomson's hypothetical vortex-atoms involve gyroscopic tendencies to maintain uniform planes of rotation, which must aid the normal arrangements of æthereal particles (*Proc. Am. Phil. Soc.*, xii, 408) in the determination of axial and polar, centrifugal and centripetal relations. Hence arise various combinations of

motion and tendencies to motion, which are obedient to simple mechanical laws, and which give rise to the different classes of radiodynamic phenomena which we call gravitating, electric, magnetic, thermal, chemical, etc. In consequence of the universality of motion, which seems to make absolute equilibrium an absolute impossibility, the tendencies to division in extreme and mean ratio are never repeated in the same exact plane, but they partake of a more or less intricate spiral character, such as is uniformly shown in vegetable growth. The comparative relative stability of axes, even in ultimate molecules and atoms, must produce æthereal oscillations which are parallel to the axis, as well as those which are radial and tangential (*Op. cit.*, ix, 408), giving rise to solenoidal currents, such as are assumed in Ampère's hypothesis.

213. *Earth's "Pulsation Period."*

Proctor (*Contemporary Rev.*, March, 1882, p. 479), speaks of "the time when the Earth's rotation began to approach to synchronism with her pulsation period" or "the period of vibration of her mass after any impulse (affecting the whole Earth) had been received from without. The Earth would as certainly have had such a pulsation period as the vibrating substance of a bell has." This admission is interesting as an evidence of increasing recognition of the truths which are involved in Herschel's doctrine of nebular elasticity or quasi-elasticity, and which are the groundwork of all my harmonic researches. Proctor, however, in trying to explain the supposed retardation of Earth's rotation, overlooks the more than three hundredfold acceleration which Laplace's hypothesis would require.

214. *The "Reproach" of Thermodynamics.*

The hypothesis that stellar systems are cooling, condensing and giving out heat, imparting their *vis viva* to the luminiferous æther without receiving anything in return, and that, consequently, all things are tending to ultimate physical stagnation and universal death, is so unphilosophical and altogether unsatisfactory as to show that some important element must have been overlooked. If we were granted infinite elasticity, or a medium acting under elastic laws but without density, Laplace's supposed instantaneous transmission of gravitating action might be represented by well-known physical formulæ. In other words, if we could conceive of a material medium endowed with qualities which are not material, some of the difficulties of pure materialism would be removed. What name could be given to such a medium, but spirit? Spiritual, conscious, "upholding" and controlling power is conceivable; without such a conception, the most important of all phenomena are wholly inexplicable. Any hypothesis that an unconscious universe could ever have wound itself up like a clock, is childish; the belief that, after having wound itself up, it would allow itself to run down without winding itself up again is more childish still. The confession that we can see no escape from final stag-

nation imposes no restraint on the universe; it is only a confession of our own shortsightedness. He who sees the necessity of a Wise, Everlasting and Almighty Omnipresence, also sees that the present order of things must continue as long as its Ruler wills. He who sees that the Omnipresent Power acts "in ways which may be represented by harmonic or cyclical undulations in an elastic medium," also sees that more is implied in the equality of elastic action and reaction than has yet been fathomed by the sounding line of the most skillful analysis.

215. *Tides.*

The danger of hasty generalizations from investigations which are necessarily of a partial character, is well illustrated by the various speculations which have been set forth about tidal action. The equilibrium-hypothesis and each of the dynamic hypotheses have severally considered important relations and interactions between the disturbed and disturbing bodies, but the incompleteness of them all is shown by our inability yet to explain some of the phenomena which are of daily occurrence, as well as by our complete ignorance as to the normal position of the tidal crests. Bernouilli, and Laplace for certain mean depths of ocean, assumed that it should be high water under the moon; Laplace for other depths, Delaunay and Airy have given satisfactory evidences of tendencies to high tide when the moon is in the horizon; sailors have a prevalent belief that the high water, in mid-ocean, lags about three hours behind the moon; many mathematicians think that either friction or inertia may produce such lagging, but it has never been shown that there is any tidal friction, or that inertia can delay any normal tidal action. Some of the most satisfactory results have been reached through considerations of the elasticity which is involved in wave-propagation, but the inter-molecular elasticity, the extent to which the several particles of water are free to fall towards or recede from the attracting body, and the variations of weight consequent on variations of gravitating tendency, have not been sufficiently studied.

216. *Barometric Analogy.*

Fortunately, upon at least one of the foregoing points, we can ask nature a simple question, to which she gives a satisfactory answer. Is there any evidence of tidal disturbance of weight? Yes, in the daily fluctuations of the barometer. They are certainly tidal, even if we fail to see in them any likeness to the ocean tides. The air, which is heated and expanded by the sun's rays, is carried forward by the earth, in its orbital revolution and daily rotation, with a continual tendency of each particle to maintain the instantaneous direction of its motion. This tendency is represented, not by the simple momentum of the particles, but by their *vis viva*, and is accompanied by gravitating tendencies, which are sometimes antagonistic and sometimes co-operative, towards the earth and towards the sun. Their own elasticity concurs with the elasticity of any intervening me-

dium, in adjusting their relative positions to the ever-varying requirements of equilibrium, and causing harmonic oscillations which are easily traceable by means of systematic barometric observations. There can be no friction, provided the adjustments are made by the simple approach or separation of particles, and such appears to be the case. In the most thorough series of observations that has been published for any station near the equator, the harmonic oscillations are of the simplest character conceivable, representing the quarter-daily sums of the instantaneous tendencies and the changes in atmospheric weight so accurately as to give an estimate of Sun's distance, which differs by less than one-half of one per cent. from the latest astronomical estimates (*Proc. Am. Ph. Soc., ix, 287; x, 375–6, foot note.*)

217. *Ratio of Tidal Adjustments.*

Sir William Thomson has found a partial solution of the theoretical requirements of terrestrial rigidity, in his theory of vortex atoms. Perhaps the solution may be completed by supposing an intermolecular elasticity which is greater than that of glass, instead of a rigidity which is greater than that of glass. The influence of atmospheric pressure on the height of ocean tides, which has been noticed by many observers, suggests the likelihood that the whole mass of the earth may contribute to the adjustments of equilibrium which satisfy tidal tendencies. If that is the case, the entire change which would be required in the distance between any two molecular centres is less than $\frac{1}{4000000}$ of their mean distance, even at the spring tides, when the sun and moon combine their disturbing energies. The whole adjustment might be accomplished, through æthereal elasticity, in less than $\frac{1}{20}$ of a second, but it only needs to be accomplished four times in about 25 hours.

218. *Summation of Tendencies.*

The triumphs of calculus spring from the fact that its differentials represent only tendencies and its integrals are summations of tendencies. No integration or series of integrations can be rightly looked upon as conclusive, unless it has been extended to all the tendencies which can have any bearing upon the problem which we are examining. Nothing is more certain than mathematics, except our knowledge of our own spiritual existence and faculties. Neither in mathematics nor in psychology, however, is it safe to assign any value to our results beyond their necessary relations to the data from which they were obtained. Delaunay's hypothesis of tidal friction undoubtedly follows from his postulates, and if we accept it, we may be satisfied with the explanation which it gives of apparent lunar retardation, but his postulates are not all axiomatic; they do not cover the whole ground; and the errors in the lunar tables may spring from some portion of a cycle of mutually compensating perturbations. The tidal tendencies are towards accelerated rotation in two of the quad-

rants and towards retarded rotation in the other two, the sum of the accelerating being exactly equal to the sum of the retarding tendencies. No evidence has ever been adduced of any actual lagging of the water to maintain the normal position of the tidal crests relatively to the moon. There are many reasons for believing that the apparent westward motion, with a mean equatorial velocity of 1000 miles an hour, is only a motion of form, maintained by the combined influences of intermolecular elasticity, atomic elasticity or quasi-elasticity, variations of pressure on account of varying attraction, and such wave propagation as may be needed for the adjustment of opposite meridional and horizontal, static and dynamic tendencies. The adjustment may be brought about, as I have shown in Note 217, without any frictional diminution of the speed of rotation.

219. *The Moon and the Chief Planetary Belt.*

The importance of Earth's position, at the centre of the belt of greatest condensation, is further shown by the harmonic reactions between the Jupiter-Saturnian belt and Earth, with its satellite. The shortening of rotation-period which would represent a nebular contraction of Sun from Jupiter's to Earth's mean locus, corresponds to the shortening which would represent a contraction from Moon's semi-axis major to Laplace's terrestrial limit; the ratio between Moon's synodic and sidereal periods corresponds to the ratio between the locus of Saturn's incipient subsidence (secular aphelion) and axis-major. The time of rotation, in an expanding or contracting nebula, varies inversely as the square of radius:

$(\rho_5 \div \rho_3)^2 = 5.2028^2 = 27.06912.$
Sidereal month ÷ day = 27.32166.
Synodic ÷ sidereal month = 1.08087.
Saturn's sec. aph. ÷ mean* = 1.08433.

220. *Stability of Rotation-Periods.*

The relations of stellar rotation to oscillations which are propagated with the velocity of light, the relations of primary planetary rotation to planetary revolution, the relations of molecular rotation to electric, magnetic and tidal phenomena, the constancy of tendencies to harmonic oscillation, the confirmation of nebular theories which is afforded by the foregoing note, and the principle that no change in the *vis viva* of a system can take place without foreign action, all indicate a stability of rotation which is inconsistent with the hypothesis of tidal friction. Moreover, the closeness of accordance between the mean daily thermal and hygrometric adjustments of elasticity and the tidal variations of atmospheric pressure (*Proc. Am. Ph. Soc., ix, 284–6, 291–3, 346–8*), an accordance which is also shown in the lunar-monthly barometric tides (*Ib., 395–9; Proc. Roy. Soc. xiii, 329–33*), furnishes additional grounds for believing that rotation is only modified revolution, that its period is deter-

* According to Stockwell.

mined by a summation of all the tendencies to revolution which bear upon each and all the molecules of the rotating body, and that tidal variations of weight or pressure are as important in earth- and ocean-tides as in atmospheric tides.

221. *"There is much Virtue in If."*

Some extracts from a lecture by Dr. Ball, the Astronomer Royal of Ireland, have lately been largely copied by the newspapers. They contain a statement that the moon was once only 40,000 miles away, and that it thus acted as a geological engine of transcendent power. The statement is somewhat qualified by the proviso that if the present tides are three feet, and if the early tides were 216 times their present amount, then it is plain that the ancient tides must have been 648 feet. This qualification is not sufficient, and it is misleading, because it will be generally understood as covering all the points about which there is any uncertainty. Science in its claims of exactness, cannot afford to hazard any claims which can be easily refuted. It is true that there are many astronomers who believe that Delaunay's views are correct, but there are probably few who think that they have been conclusively demonstrated. If the moon pulls the ocean-waters around the earth, in a direction opposite to its daily rotation, at the rate of a thousand miles an hour, or at any less rate; if the friction, which would result from such a pull, is not compensated in some way which is not yet fully known; if there is a bulge of tidal water which cannot fully keep up with the moon, and which, by its attraction on the moon, tends to retard its orbital velocity; if all the mathematical conclusions which it seems reasonable to draw from such supposed retardation are correct, and if the "reproach" of thermodynamics must be accepted without qualification, the moon may be receding from the earth.

222. *Weakness of the Postulates.*

In examining the provisos of the foregoing note, we find:—In the first place, no tidal currents have ever been observed which indicate a lagging tendency in ocean waters. Secondly, there is no evidence whatever to show that the earth's rotation has been retarded by friction. Thirdly, there is no evidence to show that the moon's orbital motion has been retarded by the ocean tides. Fourthly, the number of elements which must enter into any calculation of planetary disturbances is so great that no prudent mathematician ever looks for more than an approximation to such results as he desires. Fifthly, the difficulties which are encountered in trying to explain irregularities of orbital motion, are vastly enhanced when we come to deal with the complicated tendencies of planetary rotation. Sixthly, there is as much reason to believe that the moon may be gradually falling to the earth, as there is to believe that the earth may be gradually falling to the sun. Seventhly, the accelerating and retarding tendencies of æthereal elasticity and resistance are but little understood. Eighthly, all of the possible compensatory adjustments, to which I have

referred in foregoing notes, should be thoroughly investigated before forming any conclusive opinion respecting Delaunay's hypothesis. Ninthly, even after such investigation, the remembrance of other possible unknown influences should prevent anything like dogmatical assertion.

223. *The "Ifs" of Elasticity.*

I shall not shrink from any criticism such as is implied in the following "retort courteous": If there is a universal æthereal medium; if it is endowed with an elasticity somewhat like that of gases; if its velocity of wave-propagation can be expressed by the ordinary formula of relation between elasticity and density; if the laws of harmonic vibration in elastic media, which have been mathematically deduced, are correct; if the æthereal *vis viva* can be shared with chemical atoms and cosmical masses; if nebular "subsidence" has been governed by the laws of gravitation; if all kinds of energy are simple functions of mass and velocity, and "if all the mathematical conclusions which it seems reasonable to draw from" these hypotheses are correct, the general postulate that "all physical phenomena are due to an Omnipresent Power, acting in ways which may be represented by harmonic or cyclical undulations in an elastic medium" may be accepted as a good working hypothesis.

224. *Acceptance of the Issue.*

These provisos cover the whole ground, as fully as I could wish. I have never claimed, nor have I believed, that any scientific thesis can be freed from the limitations which are involved in its fundamental assumptions. While I fully believe in the impossibility of anything acting except where it is, in the existence of a universal elastic medium which is governed by radiodynamic and harmonic laws, and in the uniformity of physical force, I am well aware that they are incapable of mathematical demonstration and I have repeatedly acknowledged that the nebular and æthereal hypotheses have no scientific value beyond such helpful coördination of phenomena as they may furnish. The tidal "ifs" are mere assumptions, adduced in order to account for an apparent retardation which is altogether problematical and which, if it should prove to be real, may be followed by an equivalent acceleration; the elastic "ifs" are all intrinsically probable, and instead of having been assumed for a special purpose they represent simple and natural generalizations from a wide range of independent physical phenomena. The tidal ifs are like Bacon's "barren virgins;" the elastic ifs have already led to the discovery of a vast number of natural harmonies and the field for further like discovery widens so rapidly that every physical atom seems to contribute its individual melody, to the ever-resounding and ever-changing choral strains which constitute the music of the spheres. Although centripetal and centrifugal activities may be expressed by identical formulæ, it is difficult, if not impossible, to form any definite conception of attracting pulls. Elastic thrusts are exemplified by every breath that we draw, every object that we see, every sound that

we hear, and Anderssohn* has experimentally shown that they can adequately represent all varieties of gravitating and electromagnetic phenomena.

225. *A Scientific Statement of the Tidal Problems.*

The "Astronomy for Schools and Colleges," by Newcomb and Holden (Ed. of 1879, p. 167), speaks with true scientific caution, as follows:—"The theory of the tides offers very complicated problems, which have taxed the powers of mathematicians for several generations. These problems are in their elements less simple than those presented by the motions of the planets, owing to the number of disturbing circumstances which enter into them. The various depths of the ocean at different points, the friction of the water, its momentum when it is once in motion, the effect of the coast-lines, have all to be taken into account. These quantities are so far from being exactly known that the theory of the tides can be expressed only by some general principles which do not suffice to enable us to predict them for any given place."

226. *Cometary Spectra.*

The uncertainties of measurement and the harmonic indications which are given in spite of those uncertainties may be illustrated by comparing observations of like objects by different reporters. Tacchini gives (*Ann. de Chim. et de Phys., xxv, 286*) measurements of the spectral lines in comet *b*, 1881, which correspond satisfactorily with lines in Hesselber's carbon spectrum. The harmonic accordance is equally satisfactory.

Harmonic.	Tacchini.
$37527.7 \div 68 = 551.9$	552.1
$37527.7 \div 73 = 514.1$	514.1
$37527.7 \div 81 = 463.2$	463.1

Thollon (*Ib.*, 287–8) compares the same spectrum with three different spectra of carbon compounds, viz: A, electric arc, Jamin's lamp measurements made by M. Bigourdan; B, cyanogen, coil and condenser, Salet; C, blue flame of illuminating gas, Lecoq de Boisbaudran.

Harmonic.	Thollon.	A.	B.	C.
$31479 \div 56 = 562.1$	562	562.2	563.0	562.9
$31479 \div 61 = 516.0$	516	516.5	516.3	516.1
$31479 \div 67 = 469.9$	470	470.4	470.0	470.6†

The harmonic divisors for Tacchini's measurements are sums of successive or nearly successive phyllotactic numbers: $81 = 5 + 8 + 13 + 21 + 34$; $73 = 81 - 8$; $68 = 73 - 5 = 13 + 21 + 34$. In the harmonic divisors for Thollon's measurements, $56 = 7 \times 8 =$ product of the artiad and perissad divisors, and the middle line is an arithmetical mean between the other two.

* *Der Mechanik der Gravitation*, Breslau, 1874; *J. B. des Bres. Phys. Ver.*, 1881-2.

† Boisbaudran does not give this line, but he gives 473.8 and 467.5, the arithmetical mean being 470.65.

227. *Identity of Spectral Lines in Different Elements.*

Young (*Am. Jour. Sci., xx, 355*) and Liveing and Dewar (*Proc. Roy. Soc., xxxii, 225–31*) have shown that many of the lines in different elementary spectra, which have been supposed to be identical, really differ slightly in refrangibility and can be separated by a sufficient increase of dispersive power in the trains of prisms. The number of separations which has already been effected makes it very doubtful whether any case of absolute coincidence can be found, where two elements are present in the spectral incandescence. This has been thought, by some, fatal to Lockyer's and Thalen's hypothesis that all the lines are modifications of a few basic lines. That such a generalization is too hasty, may be shown by the following considerations: 1. Atoms are continually subject to incommensurable, as well as to commensurable tendencies. 2. There are often various harmonic tendencies, which are simultaneously operative, the final harmonic adjustment being determined by the relative magnitude of the individual tendencies. 3. The well-known experiment of oscillating balls, suspended from a horizontal cord, shows that the cyclical vibrations are modified by each member of a harmonic group. 4. The slight fluctuations in the lines of the solar spectrum make it probable that there are similar fluctuations in chemical and cometary spectra. 5. This probability is increased by the differences of measurement which are made by different observers at different times. 6. Propositions 2 and 5 are both illustrated by the two harmonies which represent Tacchini's and Thollon's measurements (Note 226).

228. *Lithium Harmonies.*

Liveing and Dewar (*Proc. Roy. Soc., xxx, 93–9*) have observed three lines in the spectrum of lithium (3913, 3984 and 4273), besides Boisbaudran's line, 4131.7. The harmonies are shown below.

Harmonic Divisors.	Harmonic Quotients.	Observed.
1	4273.02	4273
$1 + 7\,a$	4132.78	4131.7
$1 + 15\,a$	3983.37	3984
$1 + 19\,a$	3912.65	3913

The coefficient of the first addition to the harmonic divisor is the same as the perissad divisor and as Prout's coefficient of Li. The second and third additions are respectively the artiad divisor and $\frac{1}{2}$ the artiad divisor. The harmony is nearly as satisfactory, if we combine these lines with those which are given by Huggins (*see Proc. Am. Ph. Soc., xvii, 297*).

Harmonic Divisors.	Harmonic Quotients.	Observed.
1	6107.37	6107.3
$1 + 40\,a$	4796.64	4794.8
$1 + 48\,a$	4599.23	4599.3
$1 + 63\,a$	4269.74	4273.
$1 + 70\,a$	4131.49	4131.7
$1 + 78\,a$	3984.31	3984.
$1 + 82\,a$	3914.50	3913.

The coefficients of a are, 5×8, 6×8, 9×7, 10×7, $10 \times 7 + 8$, $10 \times 7 + \frac{8}{2}$ of 8, being made up of multiples or sums of the phyllotactic numbers, 2, 3, 5 and 8, and the secondary phyllotactic number, 7.

229. *Relations of Central Force to Thermal Constants.*

I have shown (*Proc. A. P. S., xiv, 651*) that the ratio of heat under constant volume to heat under constant pressure, as deduced from purely theoretical considerations, is $\pi^2 + 4 : 2\pi^2$, or $1 : 1.4232$. The elements for computing this ratio are: 1, the synchronism of oscillations, under the action of central forces, in all orbits which have the same major axis; 2, the kinetic theory of gases, which supposes that all the paths of clashing particles are rectilinear, and therefore in orbits of unitary eccentricity, one extremity of each path corresponding with the centre of a synchronous circle; 3, the consequent ratio of mean rectilinear *vis viva*, or mean *vis viva* of constant gaseous pressure, to synchronous mean circular *vis viva*, or mean *vis viva* of constant volume; 4, the thermodynamic doctrine that equal quantities of heat correspond to equal increments of *vis viva* and to equal increments of temperature; 5, the proportionality of mean *vis viva* to mean distance of projection against uniform resistance; 6, the determination of the radial locus at which the mean velocity of linear oscillation, or of mean gaseous pressure, would be acquired both in centrifugal and in centripetal motion. This theoretical determination of the ratio of specific heats proceeds on the hypothesis of Boscovich, that central forces continue to act, at all distances from the centre, with accelerations which vary inversely as the square of the distance. There are many reasons for believing that this law does not hold, even in the æthereal condition, within the radius of inertial aggregation, and it seems likely that careful experiments may bring to light many kinds of deviation from the theoretical value, the study of which will greatly extend our knowledge of atomic and molecular structure. The most accurate experimental determinations of the ratio that have been published hitherto seem to range between $1 : 1.4053$ and $1 : 1.421$. These values indicate an orbital eccentricity of from .9874 to .9985.

230. *Tests of Thermal Relations by Solar Mass and Distance.*

The estimates which I have hitherto made of the central energies of the solar system, from measurable tendencies to equilibrium between gravitating and explosive or centripetal and centrifugal energies (*Proc. A. P. S., xii, 392–4, xix, 354, et al.*), have been based upon the supposition that all the calorimetric measurements were made under constant pressure. C. v. Than (*Abstr. in Jour. Chem. Soc., March, 1882, p. 265.*) gives five estimates for the heat of combustion of H_2O, from which estimates of solar mass and distance may be deduced by the method of Note 16.

	Observers.	θ	ρ	m
At constant volume	Andrews,	33,880	92,760,000	331,500
	v. Than,	33,822	92,839,400	332,350
At constant pressure	J. Thomsen,	34,218	93,071,400	334,850
	Favre and Silbermann,	34,426	92,789,800	331,820
	Schuller and Wartha,	34,471	92,729,200	331,170

The observations were made respectively in 1848, 1881, 1873, 1852 and 1877. The corresponding molecular heats, as given by Naumann (see Note 16) for three of the above observers, differ slightly from $2 \times$ the above values of θ, the greatest difference being $\frac{3}{4}$ of one per cent. The mean values, if we allow equal weight to the present note and to Note 16, after making the proper correction in the observations at constant volume, are $\rho = 92,739,500$; $m = 331,280$. This value of ρ differs by less than $\frac{1}{113}$ of one per cent. from the mean of the combined results in Note 15 (92,737,100).

231. *Molecular Volume of Solids.*

E. Wilson (*Proc. Roy. Soc., xxxii, 457–91*) discusses the relations of molecular volume to chemical constitution, furnishing new evidence of harmonic oscillation. He states the three following propositions, and thinks that his tables lend comparatively greater support to the third, while the first and second must, for the present, be considered more hypothetical:

(i.) When any number of *similar* atoms combine, the volume of the resulting molecule is equal to that of the uncombined atom.

(ii.) When dissimilar atoms combine, the volume assignable to each atom is some simple submultiple or aliquot part of its atomic volume, and the resultant molecular volume is the sum of those volumes.

(iii.) Every element in its various compounds is capable of assuming different volumes bearing a simple proportion to one another, such as 1 : 2, 1 : 3, 2 : 3, &c.

He also adduces evidence in support of Kopp's conjecture that elements may undergo different degrees of condensation in different radicles of the same compound, and he shows the agreement of his results with those which were obtained by Loschmidt from gaseous interdiffusion.

232. *Variability of Crystalline Angles.*

F. Pfaff (*Jour. Chem. Soc., June, 1881, Abstr. p. 356*) has made a series of measurements, from which he concludes that the limits of admissible correction of measured angles by calculation from rational axial sections must be carried further than has hitherto been the case. W. H. Perkin (*Ib. Aug., 1881, 409–452*), in discussing the isomeric acids obtained from coumarin and the ethers of hydride of salicyl, gives seven sets of crystalline measurements, with forty-nine comparisons of calculated and observed angles. Taking the range between the limits of observation, which are given in twenty-six of the comparisons, or the deviations of the observed

from the calculated values, in the other twenty-three comparisons, the variability is more than one per cent. in one-third of the whole number of measurements, viz: .155, .121, .067, .056, .055, .054, .046, .044, .021, .019, .018, .016, .016, .015, .012, .011. The mean variability of the forty-nine measurements is .017. These facts may have an important bearing upon many questions of radiodynamic probability, especially in regard to the adjustment of commensurable and incommensurable tendencies.

233. *Pressure.*

The experiments of Tresca and Spring, together with those of Crookes, Pictet and Cailletet, show that it is impossible to fix any boundaries between any two of the adjacent states of matter, æthereal, gaseous, liquid, solid, crystalline. J. and P. Curie (*Comptes rendus, lxxxxi, lxxxxii*) confirm Faraday's hypothesis that magnetized and dielectric bodies should tend to contract in the direction of the lines of force and to dilate at right angles to those lines, a tendency which, as I have shown,* is propagated with the velocity of light. They suppose that between the opposed faces of two contiguous layers of molecules there is a constant difference of tension, involving a condensation of electricity which depends on the distance between the two layers. By experiments with tourmaline and hemihedral crystals with inclined faces they are led to attach primary importance to the form of the molecules, the extremity which corresponds with the most acute solid angles being always negative on dilatation and positive on contraction. They deduce the following laws:

1. The two extremities of a tourmaline crystal develop quantities of electricity under pressure which are equal, but of opposite kind.

2. The quantity developed by a given increase of pressure is equal to that which is developed by an equal diminution of pressure, but of opposite kind.

3. This quantity is proportional to the variation of pressure, is independent of the length of the crystal, and for the same variation of pressure per unit of surface is proportional to the surface.

All of these results have an important bearing upon the old maxim that "nothing can act except where it is," and on Newton's consequent belief that the phenomena of gravitation can be more satisfactorily explained by æthereal pressure than by attracting pulls. They may also help to explain the formation and sublimation of heavy metallic elements, by the immense pressures to which the interior of condensing nebulæ are subjected. Many of the aggregating and dissociative tendencies of "subsidence," of which my planetary harmonies have given abundant evidence, may be exemplified chemically as well as cosmically.

234. *Test of Harmonic Probability.*

I have endeavored, in my various physical papers, to collect *facts*, through the guidance of well-known laws, and to account for them by a

*See citations in Note 200.

reference to those laws, without introducing any new hypotheses. I have already compared various phyllotactic harmonies with other chemical hypotheses, and Note 232 furnishes data for extending the tests of mathematical probability. In my first paper on the harmonic interferences in the spectra of chemical elements (*Proc. A. P. S., xvii, 297–301*) I examined the measured wave-lengths of 128 lines, in twenty-one different spectra. The greatest mean deviation of the measured lines in either spectrum from lines which are rigidly harmonic, is less than $\frac{1}{3}$ of one per cent., the mean deviation in the whole number of lines being less than $\frac{1}{13}$ of one per cent. The mean deviations in the several spectra are as follows: $\frac{1}{20}$, $\frac{1}{37}$, $\frac{2}{7}$, $\frac{1}{30}$, 0, $\frac{1}{14}$, $\frac{1}{14}$, $\frac{1}{178}$, $\frac{1}{11}$, $\frac{1}{16}$, $\frac{1}{103}$, $\frac{1}{5}$, $\frac{1}{4}$, $\frac{1}{413}$, $\frac{1}{37}$, $\frac{1}{6}$, $\frac{1}{10}$, $\frac{1}{39}$, $\frac{1}{25}$, $\frac{1}{64}$, $\frac{1}{13}$ of one per cent. The greatest deviation in any single line is one per cent., and there is only one line which has a deviation of more than $\frac{1}{2}$ of one per cent., which is only $\frac{1}{31}$ as great as the greatest deviation in Perkin's set of crystalline measurements, or less than $\frac{1}{3}$ as great as his mean variability. Later comparisons, of which Notes 226 and 228 may be taken as examples, show approximations which are still closer. The greatest deviation in Tacchini's cometary measurements is $\frac{1}{27}$ of .01, and the mean deviation $\frac{1}{51}$ of .01; the greatest deviation in Thollon's measurements is $\frac{1}{4609}$, and the mean deviation $\frac{1}{7740}$; the greatest deviation in the first lithium spectrum of Note 228 is $\frac{1}{3818}$, and the mean deviation $\frac{1}{7837}$; the greatest deviation in the second spectrum of the same note is $\frac{1}{13110}$, and the mean deviation $\frac{1}{43830}$.

235. *Spectrum of the Great Nebula in Orion.*

On the 7th of March, 1882, Huggins (*Am. Jour. Sci.*, [3] *xxiii, 335*) obtained a photograph of the spectrum of the nebula in Orion, with an exposure of 45 minutes. His former researches showed that the visible spectrum of gaseous nebulæ contains four bright lines, 5005, 4957, and two of the hydrogen lines, β and γ. The photograph has also a strong line in the ultra-violet, at the position of λ 3730, or nearly so. Some of the harmonic relations of the lines are given in the following table:

Harmonic.	Observed.
$525405 \div 105 = 5003.86$	5005
$525405 \div 106 = 4956.65$	4957
$525405 \div 108 = 4864.86$	4861
$525405 \div 121 = 4342.19$	4340
$525405 \div 141 = 3726.28$	3730

The greatest deviation is $\frac{1}{10}$ of one per cent., and the mean deviation $\frac{1}{20}$ of one per cent.

236. *Magnetic Estimate of Æthereal Density.*

Newton's æthereal hypothesis, Faraday's electric hypothesis and my own numerical relations (See Note 200) are exemplified in the following combined harmonies: Let v_e represent Earth's mean orbital velocity

which is due to Sun's attraction; v_3, corresponding magnetic component of circular orbital velocity which Earth would communicate to an æthereal particle; θ_o, specific heat of water; θ_3, specific heat of typical gas; d_o, density of Sun; d_3, density of Earth; δ_o, mean density of æther in Earth's orbit under influence of Sun's attraction; δ_3, density of Earth's atmosphere at mean locus of magnetization. Then

$$v_3 : v_o :: \theta_3 : \theta_o \qquad (1)$$
$$d_3 : d_o :: \delta_3 : \delta_o \qquad (2)$$

The given values are, $v_o = 18.476$ m.; $\theta_3 = .23773\ \theta_o$; $d_o = .25491\ d_3$. The required values are v_3, δ_3 and δ_o. From (1) we find

$$v_3 = .23773 \times 18.476 = 4.3924\text{m}.$$

At Earth's equatorial surface, $\sqrt{gr} = 4.9073 = 1.1172\ v_3$; the magnetic component of this velocity in Earth's orbital plane is $v_m = \cos.\ 23^\circ\ 28' \times 4.9073 = 4.501 = 1.0248\ v_3$; the mean locus of magnetization is therefore, $1.0248^2 \times 20{,}923{,}654$ ft. from Earth's centre $= .05028 \times 20{,}923{,}654 = 1{,}051{,}985$ ft. from Earth's surface. According to Babinet's formula (*Smiths'n Tables*, D, p. 68) the normal density of the air diminishes $\frac{1}{2}$ at the altitude

$$Z = 52494 \text{ ft.} \times \frac{30 - 15}{30 + 15} = 17498 \text{ ft.} = 1{,}051{,}985 \div 60.12$$

The atmospheric density at the locus of magnetization is, therefore $\delta_3 = 1 \div 2^{60.12} = 1 \div 1{,}252{,}920{,}900{,}000{,}000{,}000$; the æthereal density, $\delta_o = \delta_3 \times .25491 = 1 \div 4{,}915{,}148{,}000{,}000{,}000{,}000$. The density of hydrogen is .0692, or, according to this estimate, $340{,}128{,}200{,}000{,}000{,}000\ \delta_o$. This is 2.07 per cent. greater than the estimate which was based on the ratio of projectile gaseous energy to æthereal energy (Note 35). The significance of proportion (1) is increased by the cosmical relations of Joule's equivalent (*Proc. A. P. S.*, xix, 20). The agreement would be exact if we take $\rho_3 = 92{,}809{,}500$ miles.

237. *"Subsidence" Estimate of Æthereal Density.*

Subsidence towards the three chief centres of nebulosity, (Jupiter), condensation, (Earth), and nucleation, (Sun), should be influenced by æthereal harmonies. If we take the estimate of Sun's mass which satisfies the requirements of subsidence and oscillation (331776; Notes 5, 23, 91) and the British Nautical Almanac value for Earth's distance, measured in Sun's semi-diameters (214.45), $\rho_3 = 92{,}785{,}700$ miles; the mean projectile locus of the chief centre of gravity in the system (c. g. Sun and Jupiter at mean perihelion) $= 1.018\ r_o = r_e$; L_o (solar modulus of light; Note 75) $= 474657\ r_o = 465896\ r_e$; the mean locus of magnetization, $l_3 = r_e \times \rho_3 \div L_o = 199.1555$ miles $= 1{,}051{,}541$ ft. $= 60.09498 \times 17498$. This gives, for the ratio of hydrogen density (δ_h) to æthereal density,

$$\delta_h = 334,280,400,000,000,000\ \delta_o$$

which exceeds the estimate of Note 35 by less than $\frac{1}{8}$ of one per cent.

238. *Rotation Estimate of Æthereal Density.*

The hypothesis that hydrogen is the simplest known form of æthereal condensation and that all other chemical elements are condensed hydrogen, together with the theory that stellar rotation is due to æthereal harmonic oscillations (Notes 17, 34, 198 *et al.*), requires that the linear oscillations of the kinetic gaseous theory should be made circular, within the stellar nucleus. Since gaseous density varies inversely as volume, the æther-hydrogen hypothesis is satisfied by the proportion

$$\pi L_o^3 : r_o^3 :: \delta_h : \delta_o$$

$$\therefore \quad \delta_h = 335,961,800,000,000,000\ \delta_o$$

which is $\frac{1}{2}$ of one per cent. greater than the estimate of the foregoing note.

239. *Æthereal Elasticity.*

The velocity of light (v_λ), according to the subsidence estimate, is $92,785,700 \div 497.827 = 186,381$ miles. The velocity of sound in hydrogen, according to Dulong, is 4163 ft. If we designate the ratio of elasticity to density ($e \div d$), for hydrogen and æther respectively, by ε_h and ε_o, the proportionality $v \propto \sqrt{\varepsilon}$ gives

$$\varepsilon_o : \varepsilon_h :: (186381 \times 5280)^2 : 4163^2 :: 55,880,460,000 : 1$$

for the relative elasticities under the same density. If we adopt the rotation estimate of comparative density, we have

$$e_o : e_h :: 1 : 6,012,151$$

for the relative elasticities at normal density.

240. *Æthereal Density at Mean Planetary Loci.*

The æthereal density should be $\frac{1}{2}$ as great as at Sun's surface at $\frac{2}{3} L_o = 316,438\ r_o = 1448.343^* \rho_3$. At any other locus, ρ_n, it should be $(\frac{1}{2})^n$, n being equivalent to $(\rho_n \div 1448.343\ \rho_3)$. This gives, for the relative rotation estimate of æthereal density at Sun's surface and at the several planetary mean distances:

Sun	1.00000
Mercury	.99981
Venus	.99965
Earth	.99952
Mars	.99927
Jupiter	.99751
Saturn	.99544
Uranus	.99086
Neptune	.98373

* Allowing for rupturing centre of gravity of Sun and Jupiter.

241. *Validity of Estimates.*

All estimates of this character are, of course, only provisional, and they can claim no validity, as I have heretofore shown, beyond the accuracy with which they represent the data upon which they are based. That all the æthereal elements which I have considered are important, that they are more far-reaching than those which have been introduced into any like discussion of which I have any knowledge, that their influence has been rightly stated, and that they will contribute, by collation with Thomson's and other estimates, to a more satisfactory solution of many physical problems than is yet attainable, I fully and unhesitatingly believe. Sun's orbital motion, and questions connected with the retardations which change revolution into simple rotation, are among the considerations which seem likely to modify the values that are given in the five foregoing notes and in Note 35.

Note on the Aurora of April 16–17, 1882. By H. Carvill Lewis.

(*Read before the American Philosophical Society, April 21, 1882.*)

The aurora of Sunday evening, April 16–17, 1882, was probably one of the most remarkable, both as to beauty and scientific interest, that has been observed in this latitude. It is especially noteworthy on account of the brilliant *corona* which continued well defined for several hours, and whose apparent motion eastward, through space, could, therefore, be determined. Several other unusual features, such as an *auroral curtain*, and hyperbolic curves of light, were also displayed. The attendant solar and magnetic phenomena have also been of great importance in determining a theory of the aurora.

The aurora was noticed as soon as twilight had ended as a faint glow along the northern horizon. At 8.30 it was a low arch, probably not over 10 degrees high. It gradually rose higher, and left a dark segment below it. At 10 P. M. the arch was some 20 degrees high, and was constantly increasing in brilliancy. Bright short white acicular streamers now appeared in the north, and sometimes rose as high as 40 degrees. These occasionally assumed a reddish color, and were frequently wafted along the arch towards the west. The aurora now fluctuated greatly in brilliancy, sometimes nearly disappearing, and then flashing out brighter than ever.

At 11.15 the arch had become brighter and much longer, though still of low altitude. Bright acicular streamers were crowded closely together at the western end of the arch, while in the east a second arch was now formed. The auroral arch now began to rise rapidly. At 11.20 the upper arch was 40 degrees high. Long narrow streamers were rapidly forming over the whole northern sky, and were traversed from base to apex with

swift, tremulous waves of light. At the same time a mass of fine red color appeared in the north-west, and flashed alternately bright and dark, as though a red cloud illuminated by heat lightning. This mass of red color moved rapidly westward and was preceded by remarkable flashes of red. At 11.25 the aurora had risen nearly to the zenith, and was of great brilliancy. Numerous narrow streamers, covering the entire northern half of the sky, were flashing bright and dark with great rapidity, while fine crimson patches appeared independently in several portions of the sky.

At 11.30, or a few minutes later, the whole aurora from all sides moved with a bound toward the zenith. Streamers shot up from north, east and west with rapid, tremulous motions, reaching higher and higher with each pulsation, until, after apparently several ineffectual attempts, they all converged at a point nearly on the meridian nineteen degrees south of the zenith to form a corona of great beauty. This corona, which at first was unsteady and continually broken into detached segments, had become, at 11.40 P. M., a constant feature. Streamers now radiated from it in every direction, south as well as north. The whole sky seemed in motion except this one point. Rapid waves traveled along the narrow streamers from the horizon nearly up to the corona, while great nebulous masses and broad bands of crimson light flashed out in different portions of the sky. These masses of red light, particularly noticeable in the north-west, had no definite form, and showed no undulating pulsations like those of the thread-like streamers, but either hung steadily in the sky for some minutes, or else were illuminated with flashes like lightning. The impression was given that these red portions of the aurora were distinct phenomena, disconnected from the greenish-white streamers, and, perhaps, at a greater distance from the earth.

The centre of the corona appeared to be some 12 degrees east of Arcturus. At 11.50, the centre of the corona was estimated to have the position R. A. 204°, Dec. 21° 30′.

At midnight the corona, a perfect star of light, had become wonderfully beautiful. The brilliancy of the whole aurora was concentrated at this point, the horizon being comparatively dark. Remarkable coruscations of light surrounded the corona, and these were often curved so as to approach in form a hyperbola of large eccentricity, whose transverse axis passed through the centre of the corona. The streamers between the corona and the northern horizon now united into remarkable concentric hyperbolic curves of great brilliancy, whose vertices were stationary near the corona, and whose tremulous arms, made up of many streamers, reached to the northern horizon. This form recalled the drawings made of the coma of certain comets, and suggests interesting analogies.

Still more closely did these curves of light resemble those assumed by iron filings in the vicinity of a magnet, and it is probable that they were identical.

The centre of the corona was now at R. A. 207°, Dec. 21° 30′.

At 12.10 A. M., and during the half-hour following, occurred the most magnificent sight of the evening, to which no description can do justice. The streamers, whose mass was now concentrated in the corona, had detached themselves from the northern horizon to form an *auroral curtain* of great beauty. The curtain hung some twenty degrees above the horizon, and was continually changing in form and color. The streamers, whose lower ends formed its fringe, were united above in bright hyperbolic or magnetic curves, which approached the corona within ten degrees, and which remained constant while the lower part of the curtain waved to and fro in waves of light.

The following very rough diagram may serve to illustrate the general positions of the corona and curtain:

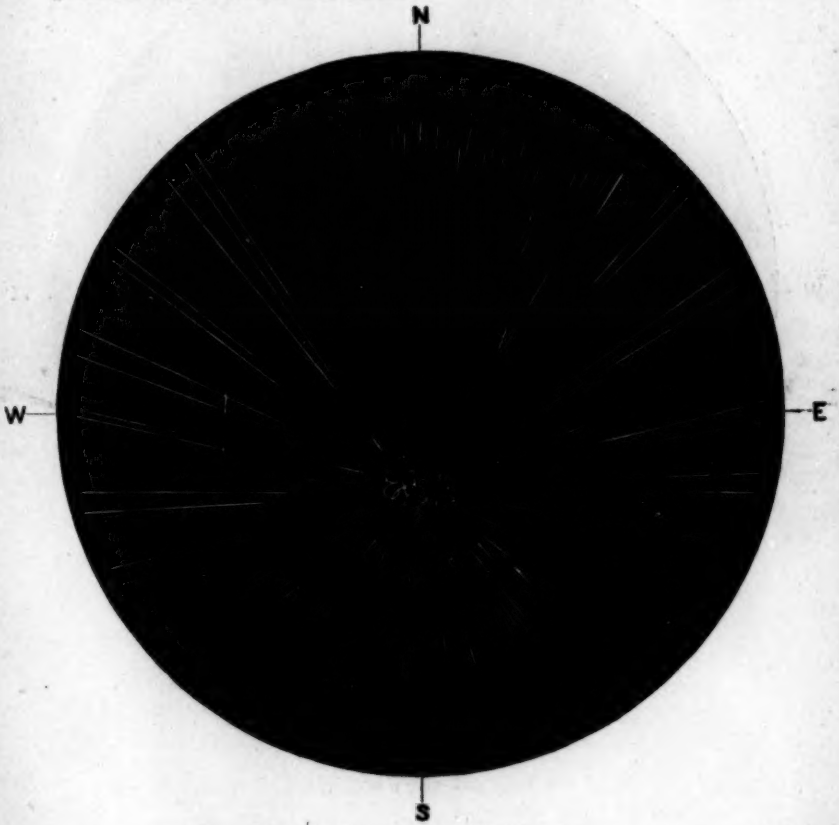

FIG. 1. AURORA AT 12.10 A. M.

A line passing through the centre of the corona and Polaris was the transverse axis of the hyperbolic curves, of which a mere suggestion is made in the diagram.

The corona itself was a somewhat elliptical crown of radiating streamers, within which was a permanent nebulous mass of light, having a *curdled* appearance. This inner curdled mass was continually moving and heaving like the sea, and was often traversed by dark rifts. It continually drifted eastward to vanish suddenly, and to be continually replaced by other cloud-like forms at the centre. Meanwhile the brilliant flashes of red light, disconnected, apparently, with the other phenomena, appeared

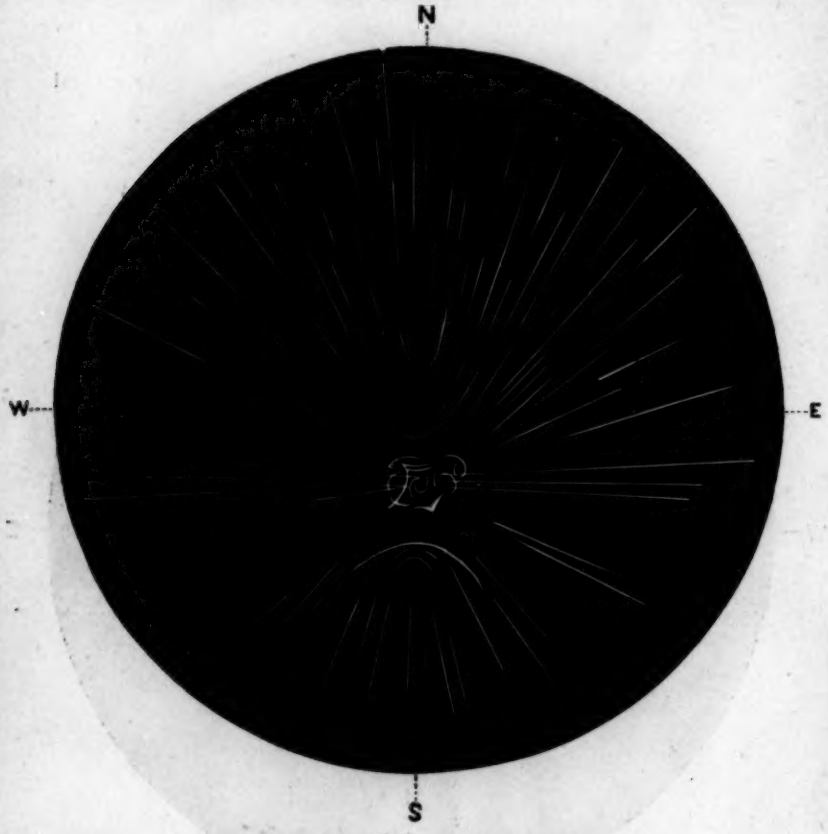

FIG. 2. AURORA AT 12.25 A. M.

in many portions of the sky, and often continued to form a back-ground for the quivering white streamers.

The streamers south of the corona presented quite a different appearance from those to the north. They were quite short, and were often broken into two or more segments, which fluctuated to and fro, but did not extend

lower than some thirty degrees above the southern horizon. At 12.20 Arcturus occupied almost the precise centre of the corona.

At 12.25 the remarkable sight was presented of two hyperbolic curves of light, the larger one lying in the north, the smaller to the south of the corona, and each pointing in an opposite direction to the other. The smaller hyperbola was bounded by an inverted arch of light in the south, some 30 degrees above the horizon. Straight lines of light, like a conjugate axis, passed east and west from the central point between the hyperbolas. The definite boundary of the southern auroral curtain may furnish data for a determination height of the aurora above the earth's surface. The appearance of the sky at this time is rudely represented in Fig 2.

It is evident that the phenomena now seen was no mere effect of perspective. The auroral streamers had become curved in obedience probably to the laws of magnetic force around a pole.

At 12.35 the corona was near R. A. 215°, Dec. 20° 30′, and at 12.45 near R. A. 216°, Dec. 20° 30′. At times the corona was a perfect star-like crown, with a small white cloud of light in the centre. Sometimes, however, it would vanish completely for a few moments, to reappear with greater brilliancy. The curdled cloudy matter within it occasionally took fantastic curved forms, and at the same time the surrounding streamers would form curves at their extremities close to the corona. Once the streamers above and below the corona moved for a short space slowly around it, in the direction of the hands of a clock.

At 1.05 A. M. the corona was estimated at R. A. 224°, Dec. 20°, and at 1.10 at R. A. 226°, Dec. 20°. By this time it had become fainter, and it frequently disappeared for a period. The aurora in the north continued until daylight. Special attention was directed to mapping at intervals during the continuance of the corona, its exact position among the stars, in order, if possible, to determine any proper motion of its own. The central point could always be determined by projecting the paths of streamers to their converging point.

The following map represents the approximate successive positions of the centre of the corona, and the time of each observation. With the exception of the position given for 11.40 P. M., which was estimated from memory, the positions here given are as plotted at the time upon the star-map.

Upon examination of this map it is at once evident that during the two hours in which it was observed, the corona had an eastward motion through space, and that this motion was at the rate of 15 degrees an hour, or precisely the direction and amount of the earth's rotation upon its axis. It was as if the corona had been fixed permanently to the earth, and the observation is a strong confirmation of the theory that the aurora is a truly terrestrial appendage.*

* The writer has previously (v. Proc. A. A. A. S., Boston, 1880, vol. xxix., p. 245), described a phenomenon noticed in the aurora of May 2, 1877, which, though less conclusively, leads to the same deduction. In that case an auroral comet-like streamer remained in a constant position, with regard to certain trees, for the space of nearly an hour, being apparently fixed to the earth like a great pointer, while the stars and the zodiacal light revolved past it.

The arc described by the corona was not perfectly coincident with a parallel of declination, but, if the observations are correct, had an inclination of somewhat over 2 degrees. The pole of this arc would be considerably west of the true north. Moreover the corona was always about 3 degrees east of the meridian, a fact also indicating that the radiant point of the streamers was west of north. The corona was constantly 18 to 20 degrees south of the zenith.

It is of interest to note in this connection that each of these facts has a direct relation to the position of the magnetic needle at Philadelphia. The magnetic pole is about 5 degrees west of the true pole, and the magnetic zenith is about 18¼ degrees south of the true zenith. The corona was, therefore, within one degree of the magnetic zenith. Parallax may, per-

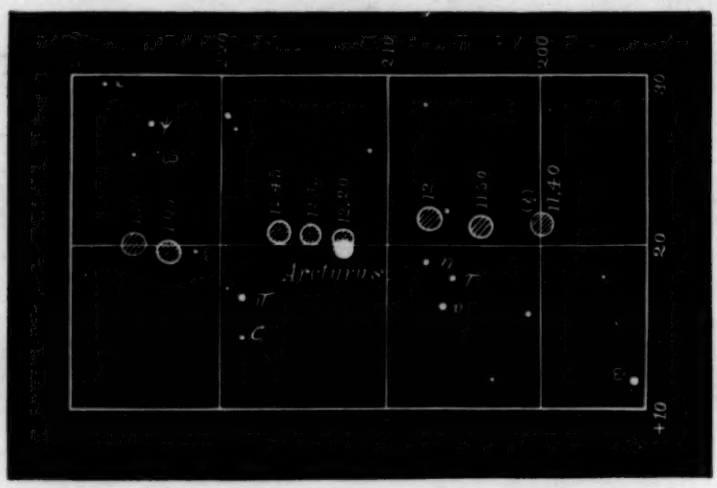

FIG. 3. MAP OF POSITIONS OF CORONA.

haps, account for the deviation, if any such exists. The position of the auroral streamers and of the corona is seen, therefore, closely to conform to the lines of magnetic force, and the connection between the two phenomena is evident.

The electrical effects of the aurora were very marked, confirming the belief that the aurora is an electrical or magnetic discharge through remote portions of our atmosphere. The telegraph wires over a large portion of the country were strongly affected by electrical currents. The wires leading from Chicago to New York, to Washington, to Milwaukee, and to Omaha, are stated to have been worked without batteries, and, after grounding the wires, messages to have been sent on the strength of the "auroral current" alone. The Atlantic cable suffered similar electrical disturbances.

The influence of an aurora upon the telegraph wires is very different from the local and transitory effects of a thunderstorm, and can always be recognized. The electrical disturbances at Philadelphia continued from midnight until eleven o'clock on Monday morning. At the office of the Western Union Telegraph Company in New York it is reported that the wires began to be affected soon after ten o'clock and that before eleven the wires in every direction were frequently interrupted. It is said that whenever an auroral current of like polarity with the battery reached the wires it neutralized the current completely and broke the circuit. In like manner auroral currents of opposite polarity, which were both powerful and frequent, would intensify the current to such a degree as to make it unsafe to use the wires. At such times brilliant sparks appeared at the ends of the keys and repeaters, which would soon burn the instruments if not disconnected. The change of polarity in the auroral current was very intermittent. Sometimes it occurred very rapidly, and at other times ten or fifteen minutes would intervene without change of current. Similar electrical phenomena are reported from many parts of the country, indicating an electrical storm of great extent.

There was no wind at Philadelphia during the aurora, and the mild spring-like weather before and during the few days since has undergone no change of consequence. Observations of this nature upon a number of auroras have led the writer to think that the popular idea that the aurora is either the cause or the result of change of weather is a fallacy. Local thunderstorms and several severe tornadoes have however occurred since the aurora in several parts of the country.

On the night of April 19–20 a second aurora appeared. There had been a severe thunderstorm early in the evening—the occasion of loss of life and property in different portions of the State—and some time after the sky had cleared, at about 1.30 A. M., there appeared a fine aurora, with high and bright streamers. As before, the telegraph wires were affected, the disturbance at Philadelphia continuing from 1 A. M. to 11.30 A. M.*

The occurrence of remarkable auroral displays at this time is a striking confirmation of the periodicity of those phenomena. It is just ten years since the last auroras of importance occurred, and the period of 10 to 12 years between maximum auroral displays may be regarded as firmly established. The coincidence of this period with that of most numerous sunspots shows a direct connection between the electrical condition of the earth and the sun. At the present time the sun is exhibiting remarkable disturbances. Upon the sun's disc are numerous and large spots which are continually changing in shape, and are traversed by solar cyclones of unusual energy. Large groups of sunspots are now visible to the naked

* The writer is indebted to the officers of the Western Union Telegraph Company for information. He also takes pleasure in acknowledging the kindness of Mr. T. F. Townsend, Signal Service Officer at Philadelphia, who has contributed his personal observations upon the aurora for use in the present paper.

eye, and one of the spots is said to be the largest which has appeared for ten years.

The theory is not improbable that sunspots are the result of solar electrical or magnetic storms, and that auroras are the result of a disturbed electrical condition of the earth, caused by induction from the sun. The common cause for both phenomena is probably cosmical.

Postscript.—Since this paper was presented, reports of an unusual auroral display have come from all sections of the country. The aurora was visible across the continent from the Atlantic to the Pacific coast. At San Francisco it is reported as the most brilliant seen for many years. A bright crimson light appeared at 8.30 P. M., and the aurora showed various colors. At Omaha a crimson sheet across the sky is described as its most remarkable feature. At Kansas City it was said to be the finest aurora since 1872, and at 12.30 the whole northern sky was lit up by streamers and red flames. At Warrenton, Mo., where it is described as the most remarkable ever seen, the light was so brilliant that signs 150 feet distant could be read. A white arch of light, extending from east to west, advanced southward at midnight to within 35 degrees of the southern horizon, and the corona was visible. At St. Louis it was seen early in the evening, and it is stated that at 11 P. M. there was no electrical disturbance in the telegraph wires. At Baltimore and Washington it was described as unusually fine, and consisting, first of a band of white light, later of shafts of colored light shooting through it, and afterwards of tremulous streamers moving with lightning rapidity, from north to south, while clouds of red fire hung in the northwest. At Richmond, Va., it was seen distinctly at 3 A. M., and is reported as the finest ever seen. At Boston, electrical disturbances were noticed shortly after the appearance of the aurora, and continued till late in the afternoon of the 17th. The wires from Boston to Albany and from Boston to New York were worked without the battery, that to New York having been worked by the auroral current alone for three hours consecutively.

In England, France, Belgium, Germany and Italy similar electrical perturbations were observed. Upon the French telegraphic lines the perturbations were so frequent from April 16th to April 20th that special measures were taken by the authorities to meet the contingency. Electrical equilibrium was restored on the 21st.

It is also of the greatest interest to learn that in England, where, so far as known, no aurora was seen, there occurred a great magnetic storm at the precise time that the aurora appeared in America. Mr. G. M. Whipple, of the Kew Observatory, in a communication to *Nature* of April 20, says "a magnetic storm of unusual intensity raged from about midnight of the 16th to midnight of the 17th," and that "a tremendous spot which appeared on the sun's disk on the 13th, is now rapidly approaching the central meridian, and a group observed on Saturday in advance of it, has undergone considerable change in the interval."

In *Nature* of April 27th, he further reports that "the magnetic disturbance began at 11.45 P. M. (6.45 P. M. Philadelphia time), April 16th, by an increase of the declination, an augmentation of the horizontal force and a diminution of the vertical force. The movements of the declinometer became gradually more rapid after 2 A. M. on the 17th (9 P. M. Philadelphia time), whilst its oscillations extended farther and farther from its normal position, principally in the direction of increased *westerly* declination. From 4.30 to 9 A. M. (11.30 P. M. to 4 A. M. Philadelphia time) the horizontal force had diminished so much that the trace frequently passed off the paper, and the register was lost for a while. The minimum of vertical force occurred at 5.55 A. M." (12.55 A. M. Philadelphia time). He states that the disturbance did not die out till about 8 P. M. on the 17th.

"During the 18th and 19th the magnets were unaffected, but at 3.45 A. M. of the

20th (10.45 P. M., April 19th, Philadelphia time), a second disturbance set in, commencing with a rapid increase of declination, the first swing of the magnet carrying it nearly a degree to the westward, whence it returned at 4.30 A. M. Its mean position was reached at 6 A. M. (1 A. M. Philadelphia time) and then its oscillations became very rapid, and continued so until 2 P. M., after which hour they became less. Both forces were also simultaneously disturbed, but their movements were much more limited than on Monday."

It is at once seen that there is a most remarkable coincidence in time between the magnetic storm in England and the aurora as seen here. The second magnetic storm also occurs simultaneously with the second aurora, and an absolute proof of the direct connection between the two phenomena is hereby established. It is interesting, also, to note that the magnetic disturbances for the most part slightly preceded the aurora, while on the other hand the electrical effects upon the telegraph wires were subsequent. This fact suggests magnetism as the primary cause of the aurora. The magnetic curves assumed by the streamers also favor this theory. The red flashes in the sky were probably accompanying electrical discharges, and many auroral effects may be due to the continual transmutation of the two forces.

Stated Meeting, May 5, 1882.

Present, 4 members.

Letters accepting membership were received from the Rev. Dr. Robins, No. 1821 Delancey Place, Philadelphia, April 26; from C. S. Sargent, dated Arnold Arboretum, Harvard University, Director's office, Brookline, Mass., April 26; from S. P. Sharples, A. M., No. 114 State street, Boston, April 29; from Franklin B. Hough, Department of Agriculture, Washington, D. C., May 2, and from George De B. Keim, No. 2009 Delancey Place, Philadelphia, April 25, 1882.

A photograph of M. Milne-Edwards was received in a letter dated Museum d'Histoire Naturelle, Paris, April 7, with a request for Nos. 97, 102, 103 to complete a set of the Proceedings.

Letters of acknowledgment were received from the New Hampshire Historical Society (110); Museum of Comparative Zoölogy (110); American Antiq. Society (110); Rhode Island Historical Society (110); Connecticut Historical Society (110); Astor Library (110); New Jersey Historical Society (110);

C. L. Doolittle (110); Traill Green (110); T. C. Porter (110); W. B. Taylor (110); J. H. C. Coffin (110); J. J. Stevenson (110); Georgia Historical Society (110); H. Phillips, Jr., (110); Wyoming G. and Historical Society (110); Numismatic and Antiquarian Society (110); Buffalo S. N. S. (110); J. M. Hart (110); Chicago Historical Society (110), and the Royal Bavarian Academy (107, 108, Trans. XV, 2).

Letters of envoy were received from the Geological Survey of India, Calcutta, Jan. 4; the Royal Bavarian Academy, Feb. 18, and Mr. Wm. Blades, 23 Abchurch Lane, London, April 17, 1882.

Donations to the Library were reported from the Geological Survey, India; Academia dei Lincei; S. C. Geog., Bordeaux; Royal Astronomical Society; London Nature; Mr. W. Blades; Harvard University; Boston Society of Natural History; American Historical Society; American Philological Society; Silliman's Journal; Mrs. T. P. James; American Chemical Society; American Society of Civil Engineers; Franklin Institute; Journal of Pharmacy; Mr. H. Phillips, Jr.; American Chemical Journal; U. S. National Museum; Com. Internal Revenue; Weather Signal Bureau; Board of Health, New Orleans, and Academy of Sciences, St. Louis.

The death of Ralph Waldo Emerson, at Concord, Mass., April 27, aged nearly 80, was announced.

On motion of Mr. Phillips the President was requested to consider various communications from Professors James Hall, Geo. H. Cook, and J. P. Lesley, and to memorialize the President of the Senate of New York for the complete publication of the Palæontology of that State.

And the meeting was adjourned.

Biographical Sketch of Thomas Potts James. By J. T. Rothrock.

(Read before the American Philosophical Society, May 19, 1882.)

In the line of botanists binding the present to that remote past, when our flora was as unknown accurately to Americans, as to the rest of the world, but few survive. Darlington, Sullivant, Torrey, James, within recent years have dropped out of the chain. The interest attaching to such men is more than an ordinary one. They were the last generation to which our botanical pioneers belonged, and they witnessed not only the rise of a republic in politics, but the rise of a republic in science. They could remember when in all this broad land there were not a score of botanists; when the science of plants and plant life held no recognized place in the colleges of this country; when the literature of our flora was almost exclusively foreign; when the commonest implements of exact research came from over the ocean. With them nearly the whole scientific tradition of the country disappeared. Later events find prompt and wide circulation in our scientific periodicals, but much that would interest the future is lost to the world when one of these honored witnesses leaves us to join the host that went before.

Thomas Potts James, in memory of whom this brief sketch has been prepared, is the latest whose loss we deplore.

Mr. James was born at Radnor, in Pennsylvania, on September 1, 1808. He died suddenly of paralysis at Cambridge, in Massachusetts, on Feb. 22, 1882. His ancestors were among the leaders of thought and action before and during the Revolution. They arrived in Pennsylvania earlier than Penn. His grandfather, Thomas Potts, after raising a company and being commissioned captain in 1776, raised a battalion and was made its colonel. He was also a member of the convention which assembled in Philadelphia on July 9, 1776, to form the new government. Washington and his staff were frequent guests at his house, and in it many important public letters were written. As the friend and intimate associate of Franklin it is not strange that he was one of the original members of this society.

He was also among the earliest to develop the iron interests of Pennsylvania. A great uncle of Mr. James, Dr. Jonathan Potts, was Deputy Director-General of the Hospital in the Northern Department during the Revolution, and was subsequently made Director-General of the Hospital in the Middle Department when this State and New Jersey became the seat of war.

Another great uncle, Samuel Potts, was a member of the convention which framed the Constitution of Pennsylvania, and was also elected Associate Judge. The name of the family is still perpetuated in Pottstown.

Coming then from such a stock it is not strange that the subject of this sketch developed marked intellectual traits. Indeed it would have been stranger if he had not.

Mr. James' love of botany appears to have been an early one. As stated in the Potts' memorial by the authoress, his wife and congenial life companion,—"From his youth he devoted his leisure to the study of botany, and, having acquired a knowledge of phænogamous plants, he turned his attention to the cryptogamia, making the musci a specialty." "He received his early education in Trenton, N. J., intending to enter Princeton College, but was prevented by circumstances," etc.

There are some men who acquire all the mental discipline that a college course could confer without entering those halls of learning. Mr. James was one of these. It may be doubted whether he would have earned any more honored name, or placed the future bryologists of the land under any greater obligations if he had taken an academic degree.

For almost forty years he was engaged in the drug business in this city, but never allowed the cares of trade to crowd science out of mind, and though not at the time enabled to devote all, or even much of his attention to botany, yet the years were far from being unproductive in the science to which he was so deeply attached. In 1853 the third edition of (that work, which will always be a classic book of science) Darlington's Flora Cestrica appeared. To this Mr. James contributed the portion describing the class of Anophytes, *i. e.*, Mosses and Liverworts. Though hardly thirty pages long it represents an amount of labor which is now past belief. It may in part be regarded as a pioneer work. To say nothing of the labor involved in collecting the material for that short paper, there were the critical determinations of the species and the always perplexing questions of synonyms to settle. It is needless to say that these duties were most conscientiously done, for Mr. James never worked in any other manner. Every line which he ever wrote upon a scientific subject was most carefully considered. In December, 1855, he published in the Proceedings of the Philadelphia Academy of Natural Sciences, "An enumeration of Mosses detected in the Northern United States, which are not comprised in the Manual of Asa Gray, M. D., some of which are new species."

Mr. Lesquereux informs me also that about this time he wrote another paper of similar character to the above but where, or what its exact title is neither of us can say. In the Smithsonian Report for 1867 there appeared in "A Sketch of the Flora of Alaska," prepared by the present writer, a list of the "Anophytes determined and compiled by Thomas P. James." Extending over but two pages, that list still represents a conscientious search through all the botanical literature of the region in order to bring together in a single view its entire moss flora; then, too, there are his original determinations of the specimens coming from that region which were placed in his hands.

In 1871 he published another catalogue with important notes in the now famous Volume V (of the Clarence King Surveys) which represents Mr. Watson's earliest labor in the science in which he has since become so distinguished.

In 1878 another catalogue of Western Mosses was published by Mr. James in Volume VI of the Wheeler Survey. It contains short notes, and descriptions of the less known species.

In the Proceedings of the American Academy of Arts and Sciences for February, 1879, conjointly with Leo Lesquereux, he published "Description of some new Species of North American Mosses."

At the time of his death Mr. James was engaged with Mr. Lesquereux in the preparation of "A Synopsis of North American Mosses," a work which is of greater magnitude and importance than its modest title would indicate. Together they had advanced to the Hypnaceæ, and of it Mr. Lesquereux writes to me "If I have time to finish this work, it must be published in both names."

I cannot forbear quoting what his distinguished colleague has written of Mr. James in a private letter to me. It is of far greater worth than any statement of mine can be :

"An excellent microscopist and delineator; an ardent collector of Mosses, he constantly devoted himself to their study. I came to this country in 1848, and it was only a little after my arrival here that he began sending me his mosses for determination. Our connection continued until his death. I received a letter from him but a few days before this. When I was obliged to abandon the use of the microscope he worked constantly upon sketches of all the interesting or doubtful American species and prepared for the descriptive part of which I took charge. He had, moreover, to give much time to the examination of collections of mosses sent for determination from various parts of the continent, those of E. Hall from Oregon, Macoon in Canada, Wolff and others from Illinois, so that his work and influence in the Bryology of North America have been very great, though his publications are limited to a few catalogues or memoirs." Then follows this touching tribute from his associate in what was to have been the crowning task of his active life : "As a colleague, as a man of truth, of honor, I regret him very much, but still more as an old friend. We were about the same age and I expected he would survive me for a long time." Surely such testimony from one who had constant relations with Mr. James for more than thirty years, in the same line of work, is praise indeed, and speaks volumes for the integrity and amiability of both.

In this connection I may add how cheerfully he always aided those who appealed to him for assistance in naming what to them were doubtful and difficult species. However badly prepared the specimens might have been, however common, or however worthless the material was to him, the same careful reply was always sent to the inquirer. These demands upon his time were frequent and serious ; indeed we may fairly say that during his earlier years they were detrimental to his business. But from sympathy with, and desire to aid any fellow-student he tolerated these appeals to the very last. It is almost a pity that time which had become so valuable to science, during his later, most productive years, was so freely given away.

Mr. James was as modest as he was painstaking and accomplished. It was only after the repeated solicitations of his life-long friend, Prof. Gray, that he undertook the preparation of the Synopsis of North American Mosses in conjunction with Mr. Lesquereux. When, however, he consented, he began the task with all the eager earnestness of youth. Two years of constant work made it requisite that he should rest; and with this end in view he took a trip to Europe in 1878. But even there all the time he could give was spent in association with Schimper of Strassburg, then the head of European bryology, in comparing our American species and in settling synonyms. For a whole month Prof. Schimper gave his afternoons to labor with Mr. James in this task. The result of that visit will be apparent in placing our own moss flora in proper relation with that of Europe. His industry and singleness of purpose at a time when most men seek rest were wonderful. During the last two years of his life he labored "from ten to twelve hours each day over the mosses; often three or four hours at a time without moving from his table." Only a few weeks before his death when reminded by Mrs. James that he had already worked fourteen hours that day, and remonstrated with for writing by gaslight, his reply was, "this work must be done and I have no time to rest."

The end came, and came suddenly, but he was not unprepared for it. No one whose life was as devout as his, and who lived with such entire charity toward all men, could be unprepared.

February 22, 1882, Ash-Wednesday, Mr. James left his study and attended to his religious duties in the Chapel of the Protestant Episcopal Theological Seminary of Harvard University. It was to him the very gate to Heaven, though he little knew how soon he was to pass through and into the eternal world. Services being over he returned to his work. Leaving his study, he went into an adjoining room where he was seized by paralysis of the left side, and this was followed by loss of speech and then coma, from which without awakening he passed calmly away.

We may well imagine how profound the grief over the loss of such a husband and father would be. But it was hardly less deep in the hearts of his habitual associates. A letter received from Professor Gray, who stood by as Mr. James departed, contains a passage too sacred even for a biographical sketch, but which indicates a suppressed anguish and a sense of personal bereavement more clearly than any phrase set in intentional mournful measure could do. In another place Professor Gray has given his estimate of the man, and in a single sentence explained the cause of his own noble grief—because Mr. James "*was admirable in all his relations.*"

Mr. James' active interest in botanical science, and the estimation in which he was held by his colleagues, are clearly indicated by the association he had in the learned societies of this land. He was

"Fellow of the American Academy of Arts and Sciences,

"Fellow of the American Association for the Advancement of Science,

"Member and sometime Officer of the American Philosophical Society,
"Treasurer of the American Pomological Society for 27 years,
"Officer of the American Pharmaceutical Society, and also of the Philadelphia Drug Exchange,
"Professor of Botany to the Pennsylvania Horticultural Society,
"Member of the Boston Society of Natural History,
"Honorary Member of the Massachusetts Horticultural Society,
"And of other kindred Associations."

During one of the absences of an honored member of this Society in Europe Mr. James was his substitute as librarian. There are those still living who remember how very acceptable his services were in that capacity.

This would be a one-sided and very imperfect sketch of Mr. James if it made no allusion to his public spirit as a citizen. Whatever was in the interest of education or of philanthropy interested him. During the late war he was thoroughly "Union" in his sympathies, and did duty with the First Regiment of the National Guard. He was also a member of the Union League, and an active associate of those who upheld the Government under all circumstances. His loyalty nevered wavered.

In December 1851, he married Isabella Batchelder. This most fortunate union was the result of an acquaintance which began but fifteen months before, and which grew out of a correspondence between Dr. Darlington, Miss Batchelder, Mr. James, and Dr. Gray, relative to the publication of the letters of John Bartram. For more than thirty years Mr. James found in his wife a sympathy in all his work, and a cultured mind capable of appreciating and aiding in his own literary labor.

Such marriages are blessings to both the contracting parties. Mrs. James and four children survive, and now reside in Cambridge, Massachusetts, whither he removed from here in 1867.

We mourn over the loss of Mr. James not only because he was dear to a large circle of friends, or because he was an active promoter of science, but also because his death leaves his favorite study with but one prominent representative in this land, a representative full of years and of honor.

But there is no younger botanist on whom the mantle has fallen; none appear to take up the work as these veterans cease from their labors, and in this event the world is made poorer from the loss of our former associate.

Gentle, genial man, though we realize how serious a loss your departure has been to science here, we do not mourn for you as for those over whom we have no hope; neither may we question the wisdom of the decree which opened your eyes to the full glory of the celestial splendor you had so long, patiently, trustingly waited to see.

Stated Meeting, May 19, 1882.

Present, 9 members.

President, Mr. FRALEY, in the Chair.

A letter accepting membership was received from C. W. King, dated Trinity College, Cambridge, England, May 5, 1882.

Letters of acknowledgment were received from Messrs. Downes, Hilgard, Goodfellow, Schott (109); American Ethnological Society (109); U. S. Naval Observatory (109); State Historical Society Wisconsin (110); Asaph Hall (110); C. H. F. Peters (110); Kansas State Historical Society (110); American Ethnologicol Society (110); Boston Public Library (110); Maryland Historical Society (110), and Poughkeepsie Society of Natural History (109, 110).

Donations for the Library were received from the Academia dei Lincei; Société Géographique, Paris; S. C. Geog., Bordeaux; London Nature; Academy, Brussels; Museum of Comparative Zoölogy; Cincinnati Observatory, and the Geological Survey of Canada.

Prof. Rothrock read, by appointment, an obituary notice of Thomas P. James.

Mr. Lesley read, by appointment, an obituary notice of Edward Desor.

The Rev. C. G. Ames was requested to prepare an obituary notice of Ralph Waldo Emerson.

The death of Wm. S. Vaux, at Philadelphia, May 5, aged 60, was announced, and Mr. Law appointed to prepare an obituary notice of the deceased.

The death of Chas. M. Wheatley, at Phœnixville, May 6, aged 60, was announced.

The death of Dr. George Smith, at Media, Delaware County, March 10, 1882, aged 78, was announced, and Dr. Brinton was appointed to prepare an obituary notice of the deceased.

A "Contribution to a monograph of the North American

him the communication, description, or model, except the officer to whom it shall be entrusted; nor shall such officer part with the same out of his custody, without a special order of the Society for that purpose.

6. The Society, having previously referred the several communications from candidates for the premium, then depending, to the consideration of the twelve counsellors and other officers of the Society, and having received their report thereon, shall, at one of their stated meetings in the month of December, annually, after the expiration of this current year (of the time and place, together with the particular occasion of which meeting due notice shall be previously given, by public advertisement) proceed to final adjudication of the said premium; and, after due consideration had, a vote shall first be taken on this question, viz: Whether any of the communications then under inspection be worthy of the proposed premium? If this question be determined in the negative, the whole business shall be deferred till another year; but if in the affirmative, the Society shall proceed to determine by ballot, given by the members at large, the discovery, invention or improvement most useful and worthy; and that discovery, invention, or improvement which shall be found to have a majority of concurring votes in its favor shall be successful; and then, and not till then, the sealed letter accompanying the crowned performance shall be opened, and the name of the author announced as the person entitled to the said premium.

7. No member of the Society who is a candidate for the premium then depending, or who hath not previously declared to the Society, that he has considered and weighed, according to the best of his judgment, the comparative merits of the several claims then under consideration, shall sit in judgment, or give his vote in awarding the said premium.

8. A full account of the crowned subject shall be published by the Society, as soon as may be after the adjudication, either in a separate publication, or in the next succeeding volume of their Transactions, or in both.

9. The unsuccessful performances shall remain under consideration, and their authors be considered as candidates for the premium for five years next succeeding the time of their presentment; except such performances as their authors may, in the meantime, think fit to withdraw. And the Society shall annually publish an abstract of the titles, object, or subject matter of the communications, so under consideration; such only excepted as the Society shall think not worthy of public notice.

10. The letters containing the names of authors whose performances shall be rejected, or which shall be found unsuccessful after a trial of five years, shall be burnt before the Society, without breaking the seals.

11. In case there should be a failure, in any year, of any communication worthy of the proposed premium, there will then be two premiums to be awarded the next year. But no accummulation of premiums shall entitle the author to more than one premium for any one discovery, invention or improvement.

12. The premium shall consist of an oval plate of solid standard gold of the value of ten guineas. On one side thereof shall be neatly engraved a

short Latin motto suited to the occasion, together with the words: "The Premium of John Hyacinth de Magellan, of London, established in the year 1786;" and on the other side of the plate shall be engraved these words: "Awarded by the A. P. S. for the discovery of——— A. D.———" And the seal of the Society shall be annexed to the medal by a ribbon passing through a small hole at the lower edge thereof.

SECTION 3. The Magellanic fund of two hundred guineas shall be considered as ten hundred and fifty dollars, and shall be invested separately from other funds belonging to or under the care of the Society, and a separate and distinct account of it shall be kept by the treasurer.

The said fund shall be credited with the sum of one hundred dollars, to represent the two premiums for which the Society is now liable.

The treasurer shall credit the said fund with the interest received on the investment thereof, and, if any surplus of said interest shall remain after providing for the premiums which may then be demandable, said surplus shall be used by the Society for making publication of the terms of the said premium, and for the addition, to the said premium, of such amount as the Society may from time to time think suitable, or for the institution of other premiums.

The treasurer shall, at the first stated meeting of the Society in the month of December annually, make a report of the state of said fund and of the investment thereof.